

BEFORE THE
NATIONAL TRANSPORTATION SAFETY BOARD
Washington, D.C.

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In the matter of the investigation :
of the accident involving :
Trans World Airlines, Inc. :
Flight 800, B-747-131, N93119, :
8 miles south East Moriches, :
New York on July 17, 1996 :
- - - - -X

Baltimore Convention Center
Halls A and B
One West Pratt Street
Baltimore, Maryland 21201-2499

Thursday, December 11, 1997

The above-entitled matter reconvened for
hearing pursuant to notice, at 9:00 a.m.

APPEARANCES:

Board of Inquiry:

Honorable Jim Hall Chairman	Member NTSB
Dr. Bernard Loeb	Director, Office of Aviation Safety
Dr. Vernon Ellingstad	Director, Office of Research and Engineering
Mr. Barry Sweedler	Director, Office of Safety Recommendations and Accomplishments
Mr. Dan Campbell	General Counsel

Technical Panel:

Thomas Haueter	Chief, Major Investigations Division
Al Dickinson	Investigator-in-Charge, Operations

Also Present:

Debra Eckrote
 Norman Wiemeyer
 Malcolm Brenner
 James Wildey
 John Clark
 Frank Hilldrup
 David Mayer
 But Simon
 Henry Hughes
 George Anderson
 Doug Wiegman
 Mitchell Garber
 Merritt Birky
 Dan Bower
 Dennis Crider
 Robert Swaim
 Charles Pereira
 Deepak Joshi
 Larry Jackson

Parties:

Lyle K. Streeter	Air Safety Investigator, Department of Transportation, FAA
Captain Jerome Rekart	Chief Accident Investigator, Air Line Pilots Association
Captain Robert Young	Director of Flight Operations Safety, Trans World Airlines
J. Dennie Rodrigues	Senior Air Safety Investigator, Boeing Commercial Airplane Group
Fred Liddell	Chief Investigator, International Association of Machinists and Aerospace Workers
Hal Thomas	Technical Engineer, Honeywell
Raymond Boushie	President, Hydro-Aire

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(Time Noted: 8:55)

CHAIRMAN HALL: We will reconvene this public hearing of the National Transportation Safety Board that is being held in connection with the investigation of an aircraft accident involving Trans World Airlines Flight 800, a Boeing 747-131 that occurred eight miles south of East Moriches, New York July 17th, 1996.

I would like to ask those in the audience that would like to observe to please sit down and take their seats. For those who are observing these proceedings, I would remind you that you can follow them and obtain additional information on the NTSB web site, which is www.nts.gov.

We have this morning -- before we begin the Aging Aircraft Panel and the Flammability Reduction Panel which will follow, let me state that I have been -- there have been inquiries from the parties, from the media and from everybody "are we going to finish today?" -- and I don't think there have been, you know --

Let me say that it is the intent of the Chairman that we have two very important agenda items. Both of these agenda items need -- both of these panels need -- need full time and discussion.

1 If we can have a full discussion and
2 presentation and all the parties and everyone feels
3 like they have had an opportunity to participate, we
4 might finish today, but -- however, I don't think it is
5 very likely.

6 But, if we -- well, we will just have to see
7 how the program moves us rather than -- I don't want to
8 set some artificial deadline that we all have to meet,
9 because I think these next two subjects are important,
10 important they be covered in the same type of detail
11 that we have covered the rest of the hearing.

12 I really appreciate everyone's patience. I
13 know we are into day four now, and -- but, I appreciate
14 everybody -- I appreciate everyone's attention, and I
15 just want to be sure that we continue to do as thorough
16 a job on these next two panels as we have done on the
17 previous panels that have preceded it.

18 So, again, I thank the parties for their
19 attendance this morning. I acknowledge the witnesses
20 and ask Mr. Dickinson, please, to swear in and
21 introduce the next panel which is on Aging Aircraft.

22 MR. DICKINSON: Good morning, Mr. Chairman.
23 Would the panel members please rise and raise your
24 right hand?

25 (Witnesses comply.)

1 Whereupon,
2 GREGORY DUNN, BILL CROW, GEORGE SLENSKI, KEN CRAYCRAFT,
3 IVOR THOMAS, ALEX TAYLOR AND ROBERT VANNOY
4 were called as witnesses by and on behalf of the NTSB,
5 and, after having been first duly sworn, were examined
6 and testified on their oath as follows.

7 MR. DICKINSON: Thank you. Please be seated.
8 This morning's panel consists of Mr. Robert Vannoy, Mr.
9 Ivor Thomas, Mr. Alex Taylor, Mr. Ken Craycraft, Mr.
10 George Slenski, Mr. Bill Crow and Dr. Gregory Dunn.
11 They will be questioned by Debra Eckrote, Robert Swaim,
12 Jim Wildey and Norm Wiemeyer.

13 Mr. Robert Vannoy is a Boeing Company
14 employee. He has been with the company for thirty-two
15 years. He is the current Chief of the 747 Fleet
16 Support. For the last sixteen years he has supported
17 the 747 fleet through the Customer Services Division,
18 has been involved with developing programs to analyze
19 and maintain the structural analysis on models 737, 747
20 and 767.

21 He is active in a variety of industry
22 activities related to aging aircraft structure,
23 including the Air Transport Association's Airworthiness
24 concern process. He has a Bachelor's Degree in
25 Engineering.

1 Mr. Vannoy, would you please identify
2 yourself?

3 (Witness complies.)

4 Thank you. Mr. Ivor Thomas; this is his
5 third panel this morning. He is still the Chief of
6 fuel systems and auxiliary power units and he has been
7 with the Boeing Company for thirty-one years. Just to
8 reiterate, he has a B.S. degree in Mechanical
9 Engineering from Bristol, England.

10 CHAIRMAN HALL: That's pretty good if he is
11 still in that position.

12 (Laughter.)

13 MR. DICKINSON: The third is Mr. Alex Taylor.
14 Please identify yourself.

15 (Witness complies.)

16 Thank you. He is a Mechanical Engineer from
17 the Boeing Commercial Airplane Group, and he has been
18 at Boeing for thirty-seven years. He is an Associate
19 Technical Fellow of the company and since 1974 has
20 worked in the Electrical System Standards organization
21 creating and maintaining Boeing standards for
22 electrical parts, materials and processes.

23 He is responsible for a variety of airplane
24 electrical wire and cable activities, including
25 research and development of new materials and test

1 methods, creating and maintaining the Boeing process
2 specifications that define the engineering requirements
3 for the assembly and installation of airplane wire
4 bundles, creating and maintaining the technical content
5 of the standard wiring practices which each airline
6 operator uses to maintain the airplane's electrical
7 wiring. He has a Bachelor's Degree in Applied Physics
8 from Royal Technical College in Glasgow, Scotland.

9 Next we have Mr. George Slenski. Please
10 identify yourself.

11 (Witness complies.)

12 Thank you. Oh, excuse me, I will go in order
13 here. Let's back up to Mr. Ken Craycraft. Thank you.
14 He is a Maintenance Engineer for TWA, provides
15 technical support to the Maintenance Department for
16 correcting difficult and/or repetitive malfunction in
17 the electrical systems on TWA aircraft. He provides
18 analysis of causes for mechanical delays and recommends
19 methods for improving the reliability of the company
20 aircraft.

21 He is a TWA designated representative at
22 government and industry meetings, and he is trained in
23 Boeing 727, 747, 767 models, and DC-9 and 10's and MD-
24 80's, and also Lockheed L-10-11's. He has a degree
25 in -- from the Central Technical Institute.

1 Now we will get to Mr. Slenski. This has,
2 again, been his second panel, I think. He is the Lead
3 Engineer for the Electrical Material Evaluation Group
4 at Wright Laboratory and has been there for seventeen
5 years.

6 Next we have Mr. William Crow. Please
7 identify yourself.

8 (Witness complies.)

9 He is with the Federal Aviation
10 Administration and has been in Aviation Maintenance for
11 forty years. He is currently the FAA's Supervisor,
12 Principal Maintenance Inspector for American Airlines
13 in Dallas/Fort Worth Airport in Texas.

14 Previous to his current position, some of his
15 experience includes he is a Certificate Manager and he
16 is an NASIP and RASIP Team Manager and a Regional FAA
17 Flight Standards Service Specialist.

18 In addition, he has served in various
19 maintenance positions in the Air Force National Guard.
20 He has a pilot's certificate with an instrument rating,
21 and he is a certificated air frame and power plant
22 mechanic.

23 Last, but not least we have Dr. Gregory Dunn.

24 (Witness raises his hand.)

25 Thank you. He has been in the Aerospace

1 industry for twenty-five years. He is currently a
2 member of the FAA Transport Standards Staff, Transport
3 Directorate in Seattle, Washington.

4 Since 1997 he has been assigned project
5 management duties for the FAA's Nonstructural Aging
6 Systems Project which will be addressing a White House
7 commission on aviation safety and security
8 recommendations regarding aging aircraft systems.

9 He has worked in the area of Transport
10 Category Airplanes Certification since 1990, and prior
11 to joining the FAA in 1990 he worked at Lockheed,
12 Boeing and Jet Propulsion Laboratories. His education
13 includes a Masters and Ph.D. in Electrical Engineering
14 from the University of California in Los Angeles.

15 Now I will turn the microphone over to Mr.
16 Robert Swaim.

17 MR. SWAIM: Thank you, Mr. Dickinson.
18 Airplanes are designed to an economic design life, and
19 with close monitoring and preventative maintenance the
20 airline industry has been able to re-define what that
21 design life can be and extend the number of years that
22 airplanes remain in service.

23 Extensive programs in this area have been
24 developed through close coordination between the
25 manufacturers, the airlines, especially through their

1 airline association, the ATA, and the FAA.

2 The Safety Board examined the subject of
3 aging airplanes after an April 28th, 1988 accident
4 involving Aloha Airlines Flight 243. The NTSB document
5 on that is publicly accessible and it is report number
6 NTSB AAR-89/03.

7 The accident investigation raised safety
8 issues pertaining to maintenance programs and FAA
9 surveillance of those programs. The accident became a
10 catalyst for major changes in how aging airplanes are
11 inspected and maintained, but the focus of most aging
12 airplane programs is on the structure and not on the
13 airplane systems which we have been talking about here.

14 Many of the potential ignition sources seen
15 in the previous panel may be age related. I certainly
16 had some people here yesterday talking to me after the
17 Ignition Sources Panel about just that subject.

18 This panel will be addressing aging aircraft
19 from two general perspectives. First we will be
20 discussing what the regulatory requirements are for the
21 continuing airworthiness of aging airplanes. After an
22 FAA description of what the regulatory requirements
23 are, we have Boeing, the manufacturer, who can present
24 an overview of what the aging aircraft programs are and
25 the history of how these programs have evolved,

1 especially since the Aloha accident.

2 We would like to discuss the impact that
3 these programs have on the airlines who operate these
4 airplanes, and we would then like to change the
5 direction and ask some questions and examine how the
6 airplanes are actually aging in service, take some case
7 histories.

8 Transport airplanes are extremely complex and
9 have numerous redundant systems, so we would like to
10 briefly discuss, once we are done with all of that, how
11 the airplanes are dispatched with some non-conformances
12 in some of these complex and redundant systems.

13 My first question is for Dr. Dunn of the FAA.
14 Dr. Dunn, what are the regulatory requirements for
15 airplanes that are operated beyond the original
16 economic design life?

17 WITNESS DUNN: Well, Robert, primarily what
18 you are referring to here is continuing airworthiness.
19 When you talk about continuing airworthiness there is a
20 role played in that activity by the FAA, the operator
21 and the manufacturer.

22 As it relates specifically to the FAA, there
23 is a -- excuse me -- flight standards function which
24 relates to FAA requirements that are given in Part 121,
25 and Bill Crow is here to represent maintenance aspects.

1 The other aspect of the continuing
2 airworthiness that the FAA addresses are in the design
3 requirements which are found in Part 25, the
4 airworthiness design requirements that the FAA levies
5 on the manufacturer of the aircraft.

6 In that regard we have Part 25. I believe it
7 is 1529, which basically says that the manufacturer
8 must provide instructions for airworthiness. This is
9 pretty simple, and basically it amounts to the
10 providing of maintenance instructions.

11 I will read in part what some of those things
12 are: recommended periods at which various appliances
13 and parts should be cleaned, inspected, adjusted,
14 tested and lubricated; the degree of inspections
15 necessary and applicable wear tolerances. In addition,
16 the applicant must include an inspection program that
17 includes frequency and extent of the inspections
18 necessary to provide for continued airworthiness.

19 That is basically the Part 25 design
20 requirement which must be satisfied by the
21 manufacturer.

22 MR. SWAIM: Okay, thank you very much.

23 Mr. Vannoy represents Boeing and, as Mr.
24 Dickinson indicated, has extensive experience as far as
25 these aging aircraft programs from the manufacturer.

1 So, Mr. Vannoy, can you kind of summarize
2 these aging aircraft programs as Boeing sees them?

3 WITNESS VANNOY: Yes, Mr. Swaim, I will
4 attempt to do that. Mr. Chairman, I have about ten
5 pages of work charts and some comments on the general
6 background and development of aging programs, and
7 hopefully that will further our discussion and answer a
8 lot of questions.

9 CHAIRMAN HALL: Yes, please, we would like to
10 see them.

11 WITNESS VANNOY: Today I am going to provide
12 a brief overview of the development and status of aging
13 airplane programs. My comments are specifically
14 directed towards the 747 airplane, but similar comments
15 would apply to other Boeing models.

16 As far as some general background, around
17 1980 the industry became concerned over the general
18 concept of airplane operation beyond original design
19 service objectives. Maintaining safety was the prime
20 consideration and has always been the prime
21 consideration on the aging programs.

22 When the 747 was first designed in the late
23 60's commercial airplanes had previously become
24 obsolete before twenty years. By the early 80's it was
25 apparent that this would no longer be the case. The

1 initial major concern was over fatigue cracking, and
2 the first formal aging program addressed that issue.

3 In contrast to that concern, systems on the
4 airplane provide indication when they fail, and Boeing
5 has been monitoring service data on systems performance
6 related to aging from the beginning.

7 Next chart, please.

8 (Slide shown.)

9 Here, I would like to emphasize that the
10 aging programs have been going on for a long time. We
11 have always had informal reviews of airplane structures
12 and systems to observe airplane performance. We were
13 always interested in how our product is performing in
14 the field, and we have been proactive to go out and
15 collect that data.

16 (Next slide shown.)

17 All these programs listed here, beginning in
18 1983 to 1988 were in place prior to the first 747's
19 reaching twenty years of age which happened in 1990.
20 Each of the four items or programs discussed here will
21 be separately discussed later in the presentation.

22 All these efforts have been focused on
23 assuring continued safety. I want to make that point.
24 They have not been focused on making the airplanes last
25 longer. The economic issues are worked in separate

1 ways.

2 As of today, many 747's have exceeded
3 original design service objectives. On my next page I
4 am going to provide some details relating to that. We
5 maintain that with appropriate maintenance there is no
6 specific life limit on the 747 airplanes; however, it
7 needs to be clearly understood that the aging airplanes
8 do require increased maintenance and repair activities
9 for operation beyond their original design service
10 objectives.

11 (Next slide shown.)

12 I would like to provide some meaningful
13 numbers related to the 747 fleet. Our design service
14 objective for the 747 has been 20 years, 20,000 flight
15 cycles -- and a flight cycle is one take-off and
16 landing -- and 60,000 hours.

17 Airplanes and service that have exceeded
18 those objectives are approximately 380 airplanes that
19 have exceeded 60,000 hours, and of those approximately
20 240 are over twenty years old, and approximately
21 ninety-five have exceeded 20,000 flight cycles.

22 MR. SWAIM: Where did the accident airplane
23 fit in that range?

24 WITNESS VANNOY: The accident airplane was
25 around 90,000 hours and 18,000 flight cycles.

1 MR. SWAIM: Twenty-five years old?

2 WITNESS VANNOY: It was twenty-five years
3 old. I want to emphasize that all these airplanes are
4 the classic 747's which are the 100's, 200's and 300's.
5 There were some references, estimates made previously
6 here about the number of classics operating today.

7 Boeing produced a little over 700 of the
8 classic airplanes. Today there are about 620, I
9 believe, still operating. We have also -- over the
10 last ten years we have been building the 400 model.
11 There are about 420 of those in service.

12 The first 747 entered service twenty-eight
13 years ago this month. Since then the 747 fleet has
14 logged 12 million flights and 54 million hours. Of the
15 1,140 747's that we have produced to date, several are
16 no longer in service, including approximately thirty
17 that have been disassembled and scrapped for economic
18 reasons. So, our design service objectives did set an
19 economic goal, and we are finding that there are a
20 considerable number of airplanes that are no longer
21 economic.

22 None of these airplanes were condemned or
23 considered unsafe. They were removed from service for
24 economic reasons.

25 Next chart, please.

1 **(Next slide shown.)**

2 The most well-known aging program on the 747
3 is the supplemental structural inspection requirements
4 for a document. This is known as the SSID, or SSID
5 Program. This was the first developed to address aging
6 on the earlier models.

7 The 747 documentation was first released in
8 1983 following a development process involving the
9 airlines and the FAA. The inspection requirements
10 identified in this document insures timely detection of
11 fatigue damage by requiring detailed inspections of the
12 highest cycle airplanes.

13 The SSID Program utilizes a sample fleet
14 containing some of the highest cycle airplanes. Since
15 we are looking at fatigue damage we are interested in
16 flight cycles, so the airplanes with the highest number
17 of flight cycles are put in this candidate fleet.

18 Over the years this sample fleet has
19 typically consisted of around 120 airplanes. We have
20 received some reports of cracking. The program has
21 worked adequately. It is still relied on today. When
22 we do get reports of cracking, that particular item
23 becomes an inspection requirement for the remainder of
24 the fleet.

25 CHAIRMAN HALL: Now -- well, could you give

1 us an idea of what cracking is?

2 WITNESS VANNOY: Well, when you talk about
3 fatigue cracking, it is actually -- you know, the part
4 is beginning to break open at some point. Usually,
5 fatigue cracks are found in the early stages when they
6 are very small, maybe a tenth of an inch, or -- it
7 depends on the type of structure you are looking at,
8 whether it is a lug or a piece of skin that is rivetted
9 together.

10 But, we are looking for very small cracks,
11 many of them by non-destructive test means, finding
12 them in the very earliest stages and then preparing
13 maintenance recommendations and programs to address
14 them in the rest of the fleet.

15 MR. SWAIM: But, you are talking about
16 structure here, right?

17 WITNESS VANNOY: We are talking about purely
18 structures here.

19 MR. SWAIM: Okay, and this is redundant
20 structure?

21 WITNESS VANNOY: This is all redundant
22 structure, that is correct, and we are looking for
23 the -- we are looking at the oldest airplanes, the ones
24 with the highest cycles trying to find the first onset
25 of cracking. This program covers hundreds of areas on

1 the airplane.

2 My next comment here, so far in this program
3 we have found twenty areas on the airplane where
4 cracking did occur, and that has resulted in inspection
5 requirements for the rest of the fleet. That has been
6 communicated to the airlines by Service Bulletin, and
7 the FAA has mandated those requirements by
8 Airworthiness Directive.

9 MR. SWAIM: Without getting into work cards
10 and specific inspection steps and so forth like that,
11 in general how do you approach that? Do you simply
12 collect records from the airlines, do you send out
13 teams to work with the airlines and do you have target
14 areas that you go after?

15 WITNESS VANNOY: Well, when you are talking
16 about this particular inspection program, it only
17 applies to the candidate -- or, the sample airplanes.
18 So, the airlines that have those airplanes have the
19 requirements to do this additional inspection after
20 having maintenance checks. It is an additional burden
21 on them.

22 They specifically go in and look at these
23 items per the requirements in the document. When they
24 find a discrepancy they have to -- per the
25 Airworthiness Directive they have to report it to us.

1 We report it to the FAA and begin putting together
2 maintenance recommendations for the rest of the fleet
3 so that this item will be addressed on the other
4 airplanes.

5 MR. SWAIM: Okay, I guess I am trying to get
6 a little more basic than that. How do the airlines
7 with these airplanes know where to look?

8 WITNESS VANNOY: Okay, the document provided
9 under this program tells them specifically which pieces
10 of structure. It gives them zone diagrams, very
11 specific directions and alternatives to reach the goals
12 established in the program.

13 MR. SWAIM: That document comes from the
14 manufacturer?

15 WITNESS VANNOY: It comes from us.

16 MR. SWAIM: Okay, thank you.

17 WITNESS VANNOY: This is a very specific
18 program, but it is typical of other inspection
19 requirements that may appear in either the Service
20 Bulletins or other maintenance information.

21 DR. LOEB: Excuse me. This program, though,
22 was set up based on the service history that had
23 existed prior to that, and areas of concern that had
24 been identified during the service history of the
25 airplane, is that correct?

1 WITNESS VANNOY: Dr. Loeb, this program was
2 established over a concern really for fatigue cracking,
3 and it was really set up by the changes in the
4 regulatory rules for new airplanes that came out in
5 1978 under FAR 25-571, I believe.

6 So, we had to go back on the 747 and do a
7 very detailed analysis, damage tolerance type approach,
8 and identify all the areas where fatigue cracking would
9 be a concern. It was a very large effort. It involved
10 operators and the FAA.

11 We produced the requirements, worked with
12 them to make sure that our inspection methods and
13 frequencies were workable within the industry. So,
14 this program was really established -- and the FAA
15 started off by an Advisory Circular that kind of told
16 us, you know, "this is how we want you to do it," and
17 then when we produced the document they came back and,
18 you know, put their Airworthiness Directive on it and
19 made it mandatory.

20 DR. LOEB: Okay, thank you.

21 MR. SWAIM: Okay, I interrupted your
22 presentation there, your slides.

23 WITNESS VANNOY: Okay, back to the slide.
24 Just one more comment as far as the process we have
25 been discussing. As far as finding problems early in

1 the fleet and putting out maintenance recommendations,
2 you know, this activity also occurs in the systems
3 arena.

4 Whenever we find a problem having a safety
5 implication on a systems item, we work it in exactly
6 the same manner, with early detection provide
7 maintenance recommendations, and it could also result
8 in an Airworthiness Directive, and there is quite a few
9 examples of that happening.

10 The next item I would like to discuss is
11 purely a Boeing program that was established in 1986
12 called a Fleet Survey Program. At that time, we were
13 concerned over the lack of data that we had, and there
14 was a general concern over, you know, what were the
15 effects of aging on our older airplanes.

16 We took a very proactive approach with the
17 attitude that if there were problems or something wrong
18 we wanted to be the first to know. So, we started
19 sending out Boeing teams of six people or more,
20 observing airplanes and heavy maintenance checks.

21 These people would go out and spend
22 approximately a week on the airplane that was in a
23 heavy maintenance check, and they had with them all the
24 information, the service history, and in particular
25 they would look for all known or suspected problems,

1 but also do a general surveillance of the airplane as
2 time and access permitted. During that program, which
3 is still going on today, the operator cooperation has
4 always been excellent.

5 Just a personal note; I participated in quite
6 a few of these fleet surveys and I was generally the
7 smallest person on the team and so I was nominated to
8 do all the fuel tanks, and even the horizontal
9 stabilizer tank. So, from yesterday's discussion I
10 have had quite a bit of experience crawling around in
11 fuel tanks.

12 In this program we have three basic goals.
13 We were interested in the actual condition of the
14 structure and the systems components, we wanted to make
15 sure that our maintenance publications were adequate
16 and, finally, we have always been interested in getting
17 the lessons learned on our airplane so we can
18 incorporate that into our new design activities.

19 Turn the page, please.

20 (Next slide shown.)

21 During this time we have looked at forty-two
22 of the 747 airplanes. These have always been the
23 oldest, highest time airplanes we could find at the
24 time. So, that constitutes a pretty good percentage of
25 the older fleet.

1 General comments about what we found; the
2 findings in general have indicated that the airplane
3 condition of both structures and systems is good, and
4 the maintenance that we have observed has been
5 excellent. This has been a worldwide effort. We have
6 been to every continent, and a pretty good cross
7 section of all our fleet.

8 We have had some significant results from
9 this fleet survey. Some of the first Section 41
10 cracking problems, severe problems, were found by a
11 Boeing team early on on this activity. I think Section
12 41 is probably the most well-known problem -- structure
13 problem relating to the older 747's.

14 During our survey --

15 CHAIRMAN HALL: Could you elaborate just a
16 little on that at some point, because I received -- we
17 have received a bit of correspondence on that, and I
18 would like -- you know, I think for the record it would
19 be good to have some information on that and what
20 Boeing has done.

21 WITNESS VANNOY: Yeah, the Section 41
22 cracking is basically frame -- internal frame cracking,
23 problems that showed up about 1986. We had some
24 multiple frames that were cracked.

25 CHAIRMAN HALL: Could we put a 747 up so

1 someone could point to Section 41?

2 WITNESS VANNOY: Well, if you look at the
3 older airplanes and you are familiar with the upper
4 deck and the three windows on the older airplanes, it
5 is the section right in front of and underneath the
6 three windows on the upper deck and, you know, right
7 behind the flight -- where the flight crew sits.

8 It is the nose of the airplane, and it has
9 kind of a flat part of -- the side of the airplane is
10 flat up there, and that is the forward part of the
11 airplane, the Section 41.

12 MR. WILDEY: Mr. Chairman, I would point out
13 that the Section 41/42 joint is at the very forward end
14 of the reconstructed airplane. So, that is the start
15 of the Section 41, just in front of the reconstruction.

16 CHAIRMAN HALL: Thank you.

17 WITNESS VANNOY: So, in 1986 when we became
18 aware of this concern over the multiple cracking, we
19 acted very quickly, we shared our information with the
20 FAA and the airlines by -- I think within two or three
21 days we had some maintenance information out and the
22 FAA put out a telegraphic Airworthiness Directive to do
23 a quick inspection of the airplane.

24 Within about two weeks we developed an
25 extensive Service Bulletin for internal inspections,

1 identified the requirements' initial inspection
2 threshold, repeat intervals, we had multiple operator
3 meetings to convey all this and I think the original
4 requirement was for airplanes over 15,000 cycles that
5 had to be inspected quite quickly.

6 That still carries out today. Those
7 inspections are still enforced today, maintaining
8 safety in the older 747's. We realized we needed to
9 make a design change, so we changed our design and
10 implemented that in 1987, I believe, at about line
11 position 680.

12 Then, the Aging Aircraft Task Group came
13 along a few years later and included that retrofit
14 requirement as one of the mandatory modifications in
15 aging airplane programs. So, airplanes as they exceed
16 20,000 flight cycles, they must have this mandatory
17 modification. Up until that time, they must do the
18 repetitive and internal inspections.

19 So, the program has worked very well and we
20 have --

21 CHAIRMAN HALL: The accident aircraft had or
22 had not had this?

23 WITNESS VANNOY: The accident aircraft was
24 subject to inspections, and it had repeat inspections
25 at 13,000 and 16,000 cycles, and it would have been due

1 for another at 19,000. So, it had accumulated 18-plus
2 thousand cycles.

3 CHAIRMAN HALL: But, it did not have the
4 retrofit because it was not over 20,000 cycles?

5 WITNESS VANNOY: It didn't have the retrofit
6 because the operator had chosen not to apply that yet.
7 But, I think the findings indicated that the cracking
8 was as we would have expected. It was very minimal.

9 MR. SWAIM: A matter of clarification. You
10 used the term "NDT." What does NDT stand for? What is
11 it?

12 WITNESS VANNOY: Mr. Swaim, NDT is non-
13 destructive testing, which could include x-ray,
14 ultrasonic -- different techniques that we use in the
15 industry today to look for cracking in the structure.

16 MR. SWAIM: Okay, thank you. Mr. Chairman,
17 if I could add one further point, these areas on the
18 accident airplane were examined in great detail because
19 it was a known problem, and there was no evidence of
20 any kind of fatigue cracking in that area. There is no
21 report on that, by the way.

22 CHAIRMAN HALL: Thank you. I just think it
23 is important for the record that it be pointed out that
24 it was looked at very carefully as part of the
25 investigation.

1 WITNESS VANNOY: Okay, as I was saying, we
2 found some Section 41 cracking -- in our surveys, we
3 have also found some significant findings related to
4 systems. None of those have impacted safety. We have
5 addressed those with maintenance recommendations.

6 We have also, in addition to the fleet
7 surveys, continued to take other opportunities to go
8 out to airline visits and look at systems.

9 If I could have the next chart, please?

10 (Next slide shown.)

11 MR. WILDEY: Mr. Vannoy, before you leave
12 this area, can you compare the fleet survey airplanes
13 with the candidate fleet of airplanes under the SSID
14 document? Are they the same airplanes?

15 WITNESS VANNOY: Many of the airplanes would
16 be the same airplanes. It is the same basic goal. In
17 both cases we are looking for the oldest airplanes, and
18 the SSID airplanes, the candidate airplanes are the
19 ones generally above 20,000 flight cycles, and those
20 are the ones we are also seeking out in survey
21 programs. So, many of them are the same airplanes.

22 CHAIRMAN HALL: Mr. Vannoy, you mentioned
23 that as you found system problems they have been
24 addressed through recommendations, or Service
25 Bulletins?

1 WITNESS VANNOY: That's right.

2 CHAIRMAN HALL: Do you know how many of those
3 there have been, and have there been any in regard to
4 the electrical system of the 747?

5 WITNESS VANNOY: I checked through a lot of
6 databases and results of the fleet surveys. I did not
7 find anything relating to the electrical systems. An
8 example of what we found; I know we found some
9 corrosion on the landing gear actuator that resulted in
10 some improved maintenance recommendations.

11 But, generally we are doing visual checks,
12 and even though we -- you know, we look at wire bundles
13 and we looked at everything on the airplane we could.
14 There was very little found from this survey activity
15 that would relate to any wiring or general systems
16 problems.

17 CHAIRMAN HALL: So I am clear for the record,
18 were you looking for those problems, or were you just
19 looking at structural problems and as you -- maybe
20 system -- a system problem came to your attention, that
21 was addressed, or were you looking for both?

22 WITNESS VANNOY: We were looking for both.
23 We had systems specialists on our team, and they
24 basically looked over the whole airplane; you know,
25 everything from cable runs to door systems and cockpit

1 and anything they could look at.

2 CHAIRMAN HALL: Please continue.

3 WITNESS VANNOY: Okay. The reports that we
4 were receiving from the fleet surveys and from the
5 airlines, Section 41 and other fuselage structures in
6 the mid-80's convinced us that additional data was
7 needed.

8 In 1987 Boeing acquired a 747-100 airplane
9 that had accumulated 20,000 flight cycles in service,
10 and we put that next to our factory and set up a test
11 fixture.

12 Over a two and a half year period the body
13 structure was subjected to an additional 20,000
14 simulated flight cycles. From this activity we
15 developed a detailed fuselage inspection program that
16 was defined for the fleet and published by an Alert
17 Service Bulletin. An alert designation on a Service
18 Bulletin designates a higher priority bulletin,
19 typically signifying safety implications.

20 The threshold for beginning this inspection
21 was set at 22,000 cycles, which is about ten percent
22 over our design service objective. We had extensive
23 operator meetings concerning this to explain what we
24 had found and what the requirements were going to be
25 for these older airplanes.

1 This is quite an extensive inspection
2 requirement that is on top of normal maintenance. So,
3 when the airplane gets to 22,000 cycles there is a lot
4 of extra work that has to be done here to satisfy this
5 requirement.

6 CHAIRMAN HALL: But, just on the structure?

7 WITNESS VANNOY: The structure.

8 CHAIRMAN HALL: Could I ask, just when this
9 program -- and I have had the very nice -- went out to
10 Seattle and saw this -- saw your airplane out there.
11 Is there any reason that you all did not look at all
12 the systems as well as the structure when you went
13 through the 747-100 and did this program?

14 WITNESS VANNOY: There wasn't any specific
15 reason. I guess at that time we were really focused on
16 the structure and had urgent need to do that. So,
17 there wasn't any real time established, or --

18 CHAIRMAN HALL: So, I guess -- what was the
19 Aloha accident, in '80 --

20 WITNESS VANNOY: That was '88.

21 CHAIRMAN HALL: '88, all right.

22 WITNESS VANNOY: So, just to note, to date we
23 have had about forty airplanes in the fleet that have
24 gone through this inspection, as defined by this
25 bulletin and Airworthiness Directive.

1 After we made the re-design on Section 41 and
2 some production changes, we did -- right beside that
3 test airplane, we did do also a test of a new 747
4 forward body section to validate our design and
5 retrofit changes.

6 Next chart, please.

7 (Next slide shown.)

8 Now, following the Aloha 737 accident in the
9 spring of 1988, new concerns were raised. The FAA
10 sponsored an international conference on aging
11 airplanes in June of 1988 and directed the formation of
12 industry working groups.

13 Groups were formed for structures non-
14 destructive testing and propulsion. The Structures
15 Group was the most active group, and the real objective
16 there and the new concern was we had to take a new
17 approach and we had to come up with methods that would
18 consider the combination of fatigue in the presence of
19 other damage.

20 MR. RODRIGUES: May I interrupt a second.
21 Bob, there is the wrong slide up for this part.

22 WITNESS VANNOY: Thank you, Dennis, I didn't
23 notice.

24 (Next slide shown.)

25 Sorry for the confusion there. The real

1 objective coming out of this was to find a new approach
2 where we could consider a combination of corrosion in
3 the presence of other damage such as fatigue. Previous
4 to this, corrosion and fatigue and whatever was kind of
5 considered on an isolated basis. We had to take a new
6 approach to be able to consider the combination of
7 corrosion effects.

8 Out of these programs that the Structures
9 Group developed -- they are all listed here, and there
10 is actually six items. I am not planning to discuss
11 all of them in detail, or even mention some of them.

12 They are pretty well known in the Structures
13 community, but the most notable of these programs is
14 the Corrosion Prevention and Control Program, and that
15 provided minimum requirements for inspection and
16 repair. Today it addresses all in-service airplanes.
17 So, that has had a tremendous impact on airplane
18 maintenance.

19 These industry actions initiated in 1988 to
20 address aging safety concerns have demonstrated a
21 cooperative determination to make the right things
22 happen throughout the industry.

23 Just a side comment, the detailed examination
24 that was conducted of the accident airplane, the
25 twenty-five year old accident airplane, and the lack of

1 any significant corrosion or cracking does provide
2 additional confidence that the programs are working.

3 The Structures programs, as well as any other
4 programs undertaken in this arena, are under the
5 oversight of the Airworthiness Assurance Working Group,
6 AAWG, which is sponsored by the FAA.

7 DR. LOEB: Before you continue, these
8 programs, including the original SSIP that started in
9 '83 and then all these others were not specific to the
10 747, is that correct?

11 WITNESS VANNOY: That's right.

12 DR. LOEB: They were fleet-wide across all
13 airplanes and --

14 WITNESS VANNOY: That is correct, Dr. Loeb.
15 As I indicated originally, my comments here are
16 specific to the 747, but the programs -- industry
17 programs apply to all the older airplanes; Boeing
18 models and other manufacturers, as well.

19 DR. LOEB: Your fleet surveys were also
20 across your models?

21 WITNESS VANNOY: That is correct. In our
22 fleet survey activity I think we have looked at over
23 200 airplanes in total.

24 DR. LOEB: Thank you.

25 WITNESS VANNOY: I have been in a position

1 over the last fifteen years to review all the incoming
2 data from the fleet, and it has become very evident to
3 me that since these programs were established about ten
4 years ago, you know, the number of aging airplanes have
5 exceeded our design objectives, have exceeded -- you
6 know, they have gone way up, but the serious reports
7 that we have been receiving have gone way down.

8 So, it is very obvious to me, as somebody in
9 a position to review all this data, that it has been
10 very effective, and it is generally considered a good
11 success story and one that all of us in the industry
12 are very proud to have taken part in.

13 Okay, I have discussed the Structures story,
14 but I would like to make a few comments about systems.
15 Systems performance is continually monitored throughout
16 the operation of the airplane. Systems design provides
17 multiple levels of redundancy.

18 Systems faults are apparent to performance
19 and built-in monitors, and during scheduled maintenance
20 systems go through additional functional checking, and
21 components are replaced, if necessary.

22 I think these general comments kind of sum up
23 why we haven't had specific programs dedicated within
24 the industry to collect additional data on systems.

25 (Tape change.)

1 Within Boeing we have been proactive in
2 seeking out information on aging effects on systems.
3 The airlines do provide reports to us as they identify
4 potential problems. We have monitored in-service data,
5 and that allows us to detect problems or trends in
6 early stages and provide maintenance recommendations in
7 a timely manner.

8 We have taken part in fleet surveys to try
9 and find anything related to systems that would be a
10 concern. One example of where we did use the surveys
11 to provide some maintenance recommendations was in a
12 service letter which we produced in January of 1995
13 that provided a lot of maintenance recommendations in
14 relation to wiring on high time airplanes.

15 This service letter, at the time it was
16 produced, did not include any wiring recommendations
17 inside the center wing tank. It was all airplane
18 wiring in the body wings.

19 CHAIRMAN HALL: Is there an economic design
20 life for wire?

21 WITNESS VANNOY: No, we haven't established
22 any life. Basically, the design requirements on wire
23 that we designed the airplane to and test and certify
24 are the wiring should last as long as the airplane
25 does.

1 We are committed to design, build and support
2 safe and reliable airplanes. I want to emphasize the
3 word "support." Over a thousand engineers are totally
4 dedicated within Boeing to daily support our in-service
5 fleet. They have no other job responsibilities. In
6 addition, we have several hundred engineers in customer
7 service organization that are on site throughout the
8 world at the airlines.

9 As problems are identified we take action,
10 and safety concerns receive our highest priority. Only
11 incoming information is reviewed more or less on a
12 daily basis, and safety items are keyed, and we have a
13 very robust process, not only of reporting items to the
14 FAA, but working internally for that priority. That is
15 basically a continuing airworthiness approach.

16 Just a few comments in closing. This is my
17 last slide.

18 (Next slide shown.)

19 I am not up here in a defensive position
20 trying to say that we know it all or we have done the
21 work on aging airplanes totally. There is still much
22 work ahead, and one thing that needs to be emphasized
23 is existing programs that have been established are
24 ongoing and they are all subject to continual review
25 and updates.

1 The task groups meet periodically. We had a
2 meeting earlier this year on the 747. We are
3 continuing our Fleet Survey Program. We recently
4 surveyed a domestic 747 that was delivered in 1970. We
5 hold operator conferences for communication and working
6 together efforts.

7 Every year for the last nine years we have
8 hosted regional aging airplane conferences around the
9 world inviting operators, regulatory agencies and all
10 those associated with maintenance. We recently
11 conducted a major 747 conference in September. We have
12 established some working teams.

13 I think we discussed in previous days here
14 the All Model Fuels Issues Team that -- the working
15 group that has started looking at things like bonding
16 and grounding. We have also established some airline
17 working teams to improve dispatch reliability in
18 systems areas. So, Boeing remains open. We are
19 committed to future participation in any program to
20 improve safety.

21 As a final comment, I would like to say that
22 I believe the best solutions will again come through
23 the collective efforts of our industry, relying on
24 facts and data and working together. Thank you. That
25 ends my --

1 CHAIRMAN HALL: That is an excellent
2 statement, Mr. Vannoy. Would you mind explaining for
3 the -- for us what an on condition failure is?

4 WITNESS VANNOY: Well, many systems
5 components on the airplane are subject to on condition
6 maintenance, and that means, basically, when the item
7 ceases to operate, or a circuit breaker trips, or the
8 function isn't there anymore, then it receives
9 attention and it gets replaced or maintained.

10 So, it probably means that that item is not
11 subject to what we call hard time maintenance which --
12 alternatively which would say that at a particular
13 interval you would pull it off regardless of whether it
14 is functioning or not functioning.

15 On condition means you leave it on the
16 airplane until it indicates it is not functioning
17 anymore.

18 CHAIRMAN HALL: Does Boeing -- does this
19 apply to most of the systems in the aircraft, if not
20 all, or do you have --

21 WITNESS VANNOY: That is correct, Mr.
22 Chairman, it would. Our maintenance recommendations in
23 the maintenance planning document put virtually all the
24 systems in the on condition category. There is almost
25 nothing that is -- from the Boeing standpoint, that is

1 hard time now.

2 In the airline world -- and we could hear
3 from maybe our TWA representative -- but, in the
4 airline world in their program of continuous
5 airworthiness they do monitor reliability, and when
6 they establish reliability information on components to
7 maintain the reliability and, you know, success on the
8 airplane, they do establish times when they pull items
9 off and overhaul them regardless of whether they work
10 or not.

11 Certainly that is common today, and most
12 airlines have those programs where many items are
13 pulled off at certain intervals, whatever 20,000 or
14 40,000 hours, whatever they establish for their own
15 requirements.

16 WITNESS DUNN: Mr. Chairman?

17 CHAIRMAN HALL: Yes, one -- yes. Just one
18 last comment, and then I will -- or, who -- where did
19 the voice come from?

20 WITNESS DUNN: Mr. Chairman, I --

21 CHAIRMAN HALL: Oh, I am sorry, at the end of
22 the table. I apologize.

23 WITNESS DUNN: If it would help, I can give
24 you the definition that is actually in an FAA-AC
25 Advisory Circular.

1 CHAIRMAN HALL: That would be good.

2 WITNESS DUNN: Okay, first of all I will talk
3 about what the definition is of hard time limit. Now,
4 understand I am not a maintenance person, but I am
5 reading the actual definition from the Advisory
6 Circular.

7 "Hard time limit is a maximum interval for
8 performing a maintenance task. These intervals usually
9 apply to overhaul, but are also applied to total life
10 of parts or units."

11 Now let's talk about on condition. On
12 condition does not mean fly 'til failure. That is
13 something that I think we need to be very clear about.
14 It doesn't mean you don't do maintenance until there is
15 a failure.

16 What it means is it refers to maintenance
17 done in regards to repetitive inspections or tests to
18 determine the condition of units, or systems, or
19 portions of structure. So, it refers to a repetitive
20 inspection process. You don't wait until something
21 fails to take action. Hopefully that clears up the --

22 CHAIRMAN HALL: Do you consider the wire
23 bundles and wiring be part of that systems that you
24 just referred to from the FAA regs?

25 WITNESS DUNN: Yes, it would be, but I think

1 a more complete answer could be given by our
2 maintenance representative. Mr. Crow could perhaps
3 elaborate on that.

4 WITNESS CROW: Would you like me to do that,
5 Mr. Chairman?

6 CHAIRMAN HALL: Yes, sir, please.

7 WITNESS CROW: There are three --

8 CHAIRMAN HALL: And let me just say that --
9 so, again, state for the record, we do not know what
10 caused the TWA 800 tragedy. One of the factors that
11 has been widely reported and one that is considered is
12 the age of the aircraft. It was twenty-five years old,
13 and I think we -- or, we need to look into these issues
14 and be sure that we understand.

15 I appreciate Mr. Vannoy pointing out a very
16 aggressive program that Boeing has had over the years
17 in the structure area. Obviously, what the Chairman is
18 going to be getting to is, is there any reason that we
19 need to be doing that in the systems area.

20 We have looked extensively at what was
21 referred to yesterday as a derelict aircraft, that
22 where we found that our inspectors found most of the
23 problems weren't visually available. They were
24 underneath connectors and et cetera.

25 I guess the question is, with the information

1 we are getting out of this investigation whether or not
2 this has anything to do with the tragedy of TWA 800. I
3 know the industry and the FAA are as interested, if not
4 more interested than the NTSB in getting all the safety
5 lessons we can out of an investigation that has gone
6 into the detail this one has.

7 So, that is where I am coming from, Mr. Crow.
8 So, I think any information you can put on the record
9 on what is presently being done and what we just
10 discussed, it would be helpful.

11 WITNESS CROW: All right, sir, I will be
12 happy to do that. I am going to call on Dr. Dunn and
13 also go back to his definitions in the Advisory
14 Circular, and he will -- when I share this information
15 with you, he will know exactly where I am going with
16 that. If he doesn't, I will lean over and help him.

17 There are three basic maintenance processes
18 within the air transportation industry. One of them is
19 hard times, one is condition monitor and the other one
20 is on condition. Those three particular processes are
21 really identified in the reliability programs that are
22 evident in most of the major air carriers today.

23 One of the things that I would like to
24 cover --

25 CHAIRMAN HALL: That word "most," is that --

1 do you mean all, or do you mean most?

2 WITNESS CROW: No, sir, I do not mean all,
3 and I am trying to choose my words very carefully
4 because the reliability program is not a mandatory
5 requirement of the FAR. It is, if you will, a
6 privilege that allows an air carrier to develop its own
7 reliability processes for the purposes of extending
8 appropriately the intervals between inspection and
9 changing of components.

10 CHAIRMAN HALL: Well, does TWA have a
11 program?

12 WITNESS CROW: I believe they do, sir.

13 CHAIRMAN HALL: Yeah. So, I wanted to be --
14 I didn't want to leave the opinion that they did not
15 have a program. Mr. Craycraft, you are probably going
16 to speak to that later, is that correct?

17 MR. CRAYCRAFT: Yes, sir, we do.

18 CHAIRMAN HALL: Thank you. Please go ahead,
19 Mr. Crow.

20 WITNESS CROW: For the record, let me say
21 this right up front. I don't present myself as a
22 Boeing 747 expert, or an expert on TWA. My comments
23 and my speaking are purely on behalf of flight
24 standards service, and in some cases that I will
25 identify as my opinion, as a supervisory aviation

1 safety inspector.

2 CHAIRMAN HALL: All of us are just here
3 trying to provide as much information we can in this
4 investigation to advance safety, and I noticed -- I
5 didn't -- Mr. Craycraft, how many years of experience
6 do you have in the aviation industry?

7 MR. CRAYCRAFT: Forty-one.

8 CHAIRMAN HALL: Well, I noticed there were
9 182 years of experience, and I didn't have your 41, so
10 there is clearly well over 200 years of experience with
11 this panel in the aviation industry, and -- so, that is
12 why I want to listen very closely to everything you
13 gentlemen have to say. Please proceed.

14 WITNESS CROW: For the record I would like to
15 have my colleague, Dr. Dunn, read the definitions of
16 those three maintenance processes. Again, he has all
17 ready read the hard time definition to you, and the on
18 condition definition. I would like for him to read one
19 more, which is the culmination of the three processes,
20 condition monitor.

21 WITNESS DUNN: Fortunately, I have also got
22 that available for me. Condition monitoring; "For
23 items that have neither hard time limits, nor on
24 condition maintenance as their primary maintenance
25 process, condition monitoring is accomplished by

1 appropriate means available to an operator for finding
2 and resolving problem areas. These means range from
3 notices of unusual problems through special analysis of
4 unit performance."

5 WITNESS CROW: I would like to continue by
6 saying I think, if I am correct, Bob Swaim is going to
7 ask me some questions here in a moment, and I do
8 have -- not a prepared, if you will, presentation, but
9 I will cover a lot of these things in order to try to
10 close the circle regarding continued airworthiness
11 requirements on air transport category aircraft on
12 behalf of the Flight Standards Service.

13 MR. SWAIM: Sir, where we intended to go with
14 this was to get the basics from Dr. Dunn with the FAA
15 of here is what is legally required, in general, and
16 then have Mr. Vannoy tell us basically where we have
17 been over the last ten years or so, what these aging
18 programs are in fairly general terms.

19 My intent next was to go to Mr. Craycraft.
20 As he said, he has got forty-one years with TWA, and to
21 ask him how the -- you see, we are narrowing down the
22 cone here -- how does TWA as a representative airline
23 implement all this guidance and help they are getting
24 from the FAA and Boeing.

25 That is where, Chairman Hall, if --

1 CHAIRMAN HALL: No, that is fine. Please
2 proceed.

3 MR. SWAIM: Okay. Mr. Craycraft, here is my
4 question. How do you implement all of this as far as
5 maintenance programs? You have to tie it into your
6 maintenance programs. How do you take care of these
7 older airplanes?

8 WITNESS CRAYCRAFT: Well, the programs
9 described by Mr. Vannoy and others is accomplished at
10 TWA with a continuous airworthiness maintenance
11 program. It is all under that large umbrella.

12 The continuous airworthiness maintenance
13 program includes all of the FAA mandatory program
14 requirements and is identified in our operations
15 specification manual that is approved by the FAA.

16 The maintenance program incorporates the aid
17 of a maintenance alert computer system that tracks all
18 the scheduled maintenance requirements on each aircraft
19 and provides alerts to our operational planning
20 department so that they can schedule the aircraft to a
21 TWA maintenance station to accomplish the required
22 maintenance sections.

23 We have a couple of other programs. The
24 Maintenance Operations Control System is a computer
25 program that does this tracking and alerting for the

1 scheduled maintenance.

2 We have -- we are loaded with acronyms, as
3 everybody is. We have an AMPS system, an Aircraft
4 Maintenance Planning System that tracks and provides
5 control for aircraft log book remarks, non-routine
6 maintenance items, follow-ups to log remarks and call-
7 out requirements for special maintenance activities.

8 We have a Maintenance Coordinating function
9 that is on duty twenty-four hours a day that provides a
10 continuous overview of all of our maintenance activity.
11 To support that we have an engineering staff that is on
12 duty at normal engineering hours, but are available on
13 call at any time to provide technical assistance or
14 advice to the maintenance organization. That is where
15 I fit in the organization. I have had many late hour
16 phone calls.

17 This is the way the program is identified,
18 and we -- I have a copy of the 747-100 operations spec
19 here in front of me that is about an inch thick, on
20 both pages that identify these items that were
21 described as hard time items, on condition items,
22 conditioned monitored items and things of that sort.

23 Then we further expand on the on condition.
24 There are some items which we can perform a detailed
25 test on the airplane, so we will call that an on

1 condition on the aircraft, or we have some that we feel
2 that we cannot adequately perform the test on the
3 airplane, so we call that an on condition shop item.

4 We will remove the item, send it to the
5 overhaul shop and the appropriate tests are
6 accomplished and determined whether it is operating
7 within its specifications, or not.

8 MR. SWAIM: Okay. Mr. Vannoy talked about
9 these aging aircraft programs and Boeing requirements.
10 Mr. Craycraft, how far -- well, let me rephrase that.
11 Do you follow the Boeing recommendations as far as
12 aging maintenance maintenance and these -- is it like
13 with my car that I can follow the maintenance manual,
14 but I don't really have to?

15 WITNESS CRAYCRAFT: No, sir. This -- the
16 Aging Aircraft Program in TWA was very active with
17 Boeing and the other air frame manufacturers in
18 developing the structural requirements and the detail
19 requirements that is involved in the aging aircraft
20 activity, as well as the Corrosion Control and
21 Protection Program.

22 So, we -- and many of those items are
23 mandated by AD once they are identified by the Aging
24 Aircraft Program, and we certainly follow the AD
25 requirements.

1 MR. SWAIM: Okay. Now, do you do most of
2 your own maintenance, or are you like some other
3 airlines where you contract out most of your
4 maintenance?

5 WITNESS CRAYCRAFT: This particular
6 maintenance we are speaking of here is accomplished by
7 our own mechanics, as Mr. Liddell would be glad to
8 support.

9 MR. SWAIM: Good point. We have the IAM
10 here.

11 Mr. Dunn -- Dr. Dunn, is this in excess,
12 beyond what the regulations are calling for? Is this
13 in addition to the regulations?

14 WITNESS DUNN: I can't what --

15 MR. SWAIM: I am not asking you to -- you
16 know, sir, do they comply. I am just saying, from what
17 he describes are they beyond -- are they in addition to
18 what the basic regulations call for?

19 WITNESS DUNN: This is an area that I can't
20 really describe, because you are talking about
21 specifically the operator's maintenance program

22 MR. SWAIM: Okay.

23 WITNESS DUNN: That is really an issue for
24 Flight Standards to address.

25 MR. SWAIM: Well, before we go there, Mr.

1 Crow, is that something that you feel comfortable
2 saying, whether you feel they are doing what the
3 regulations comply, or more?

4 CHAIRMAN HALL: Of course your question is
5 specifically regarding TWA?

6 MR. SWAIM: Yeah, do they do more than the
7 regulations require?

8 WITNESS CROW: I think that all of our U.S.
9 certificated air carriers exceed the minimum
10 requirements of the FAR in the work that they do for
11 continued airworthiness. I have in the past had
12 opportunity -- limited opportunity to spend some time
13 with the Trans World Airlines organization in Kansas
14 City and St. Louis, and our findings were that they
15 were doing the -- were meeting the minimum requirements
16 of the FAR and in many cases exceeding those.

17 MR. SWAIM: Okay. Mr. Craycraft, as an
18 operator again, okay? -- since you are doing your own
19 maintenance, do you do maintenance on other people's,
20 other operator's airplanes coming in?

21 WITNESS CRAYCRAFT: It is a contract
22 operation. We have done some and at different times
23 do, yes.

24 MR. SWAIM: Okay. My next question is, how
25 do you compare your airplanes with ones that are coming

1 off maintenance from other places?

2 WITNESS CRAYCRAFT: Usually the contract
3 operation that we perform on other operator's, those
4 airplanes are incorporated in our maintenance program
5 and that is the way that we repair and maintain their
6 airplanes, as if it were a part of our own maintenance
7 program.

8 MR. SWAIM: Right, but when it comes in to
9 you from somewhere else, as you receive the airplane in
10 equivalent period in its life to your own airplanes,
11 are they as well maintained as yours, are they as clean
12 as yours, those kinds of questions?

13 WITNESS CRAYCRAFT: I don't work on the
14 floor, so I really can't answer that question, Bob.

15 MR. SWAIM: Okay. I am getting a little
16 ahead of myself. I would like to go back into the
17 structural area again. One of our specialist
18 metallurgists is Mr. Jim Wildey who worked on the Aloha
19 accident, and I would like to see if Mr. Wildey has any
20 questions at this point as far as the structures.

21 MR. WILDEY: I don't have any right now, Bob.
22 I think I will save some for a little bit later.

23 MR. SWAIM: Okay, very good.

24 Mr. Craycraft, there is a large feeling
25 amongst the mechanics and pilots in the industry that

1 with deregulation and more competition in the airlines
2 that the airlines are tighter on their maintenance and
3 possibly even cutting back some.

4 What is the cost? Well, let's go back a
5 step. Is it a competitive industry?

6 WITNESS CRAYCRAFT: I think that is fairly
7 obvious.

8 MR. SWAIM: Okay, and what is the cost of
9 doing this kind of maintenance on these airplanes to
10 keep up an older airplane?

11 WITNESS CRAYCRAFT: I do not know any
12 specific cost or man-hours involved in a heavy
13 maintenance check.

14 MR. SWAIM: Mr. Vannoy, can you speak to
15 that?

16 WITNESS VANNOY: Yes, Mr. Swaim, I could give
17 you some general numbers. First of all, there has been
18 some discussion previously here about things like C&D
19 checks and what is scheduled maintenance. I would like
20 to kind of try and put that in perspective.

21 The typical airline, let's say operating an
22 older 747, would do their scheduled maintenance in the
23 form of what we call A-checks, C-checks and D-checks.
24 The A-check would be a fairly frequent maintenance
25 opportunity that would be maybe one day down time every

1 month.

2 The C-check would be more or less a yearly
3 inspection which would be about a week, or a little
4 more down time per year. Then the D-check would be the
5 heavy maintenance which comes approximately five years,
6 and it would be a month or more down time.

7 So, those are the scheduled maintenance
8 opportunities for a typical operator as one day a
9 month, one week a year and a month every five years.
10 Other than that, the airplanes are subject to line
11 maintenance, which is whatever can be done in between
12 flights.

13 So, I hope that gives a little better
14 perspective. The cost of heavy maintenance on the 747,
15 let's say a D-check where you would have the airplane
16 for a month or more, as the airplane, the older
17 airplanes have gone beyond the twenty-year threshold,
18 that cost has gone way up.

19 You might have as much as 30,000 or more man
20 hours to do a heavy maintenance when the airplane is,
21 say, fifteen years old. But, when it gets up to
22 twenty-five years old with these additional
23 requirements put on by the task groups, that number
24 could double or triple.

25 So, we are talking about a lot of man hours.

1 It is a very big airplane, a lot of surface, a lot of
2 access. The Corrosion Program that was identified for
3 the 747; if you were to take an airplane and you needed
4 to do all that activity on the airplane to, let's say,
5 baseline it, the estimate was 25,000 man hours just to
6 do all the access, the inspection and the restoration
7 of all the panels and everything you need to do. That
8 is just to accomplish the Corrosion Program that was
9 identified and mandated in 1990.

10 So, I hope that provides some perspective on
11 maintenance.

12 MR. SWAIM: Yes, sir, thank you. We found a
13 cooling tube missing from a fuel pump that we examined
14 during this investigation. We went into manufacturer's
15 records and we found a couple of prior instances of
16 that.

17 The cooling tube in the fuel pump also acts
18 as a flame arrester. Now, in testing we found there is
19 a check valve.

20 CHAIRMAN HALL: Mr. Swaim, are we -- do we
21 have anymore presentations from the panel, or are we
22 just getting into questions?

23 MR. SWAIM: We are getting into questions.

24 CHAIRMAN HALL: Well, could I --

25 DR. LOEB: I thought you were going to get

1 some information on the record from Mr. Crow that would
2 have helped to set the context and an understanding,
3 that you were going to ask some questions of Mr. Crow.
4 Mr. Crow, in fact, I believe indicated that he was
5 going to be getting some questions from you that --

6 CHAIRMAN HALL: Well, we seem to be wandering
7 here. Let's take a break for fifteen minutes and see
8 if we can't get our train of thought together. Off the
9 record.

10 (Whereupon, a brief recess was taken.)

11 CHAIRMAN HALL: On the record. We will
12 reconvene this hearing of the National Transportation
13 Safety Board. I would ask the observers to please take
14 their seats. We are in the -- on agenda item eight of
15 our hearing, which is the Aging Aircraft Panel.

16 We are now going to continue with the
17 questioning by the Technical Panel, and I will turn it
18 back to Mr. Swaim.

19 MR. SWAIM: Thank you, sir. Where we are
20 trying to go with this is to look at the Aging Airplane
21 Programs that have been set up specifically as far as
22 structure, dividing the ideas of structure and systems,
23 and develop what has happened in structure and then go
24 and look at the equivalents in systems, if there are
25 any.

1 So, with that, Mr. Wildey?

2 CHAIRMAN HALL: Let me just say what the
3 Chairman -- what the prerogative of the Chair is.
4 There are two other things that I would like the panel
5 to address, and then obviously -- and those are --
6 number one is what interface is there -- since Boeing
7 manufactures both military and commercial aircraft, Mr.
8 Slenski and the military has spent a great deal of time
9 looking at the issues, and I am sure you are familiar
10 with his report.

11 What interface is there at the government
12 level and the industry level so the military experience
13 and the commercial experience, if there are safety
14 lessons to be learned we can benefit. Maybe that is
15 already in place, but I would like to hear more about
16 that.

17 We also need to discuss the particular
18 maintenance on the -- on the aircraft accident -- the
19 accident aircraft so that we have a full discussion of
20 the issues. Once again, clearly understanding that
21 none of these items at this time -- we have any reason
22 to know that they were the probable cause of this
23 accident.

24 We do not know that, but we are trying to
25 discuss everything in a methodical way that has been

1 done as part of this investigation to try and determine
2 the cause of the accident. So, please proceed, Mr.
3 Swaim.

4 MR. WILDEY: Yes. Mr. Vannoy, I would like
5 to ask you to just provide us a little bit more
6 background, if you could, on the history of the
7 development of the methodologies of looking at how to
8 maintain airworthiness for the structure.

9 Could you give us a little bit more
10 background on the methods of doing this, such as fail
11 safe, safe life, and then eventual development of the
12 damage tolerance philosophy, please?

13 WITNESS VANNOY: Okay, I will do my best, Mr.
14 Wildey. The 747 was certified initially under
15 regulations at that time which was a fail-safe approach
16 which required redundancy, but the amount of analysis
17 to substantiate that was fairly minimal.

18 In 1978 the regulations changed to the
19 damage tolerance approach under FAR 25-571 and, as I
20 stated in my presentation, the SSID Program required us
21 to go back on those older airplanes and do extensive
22 re-analysis of the airplane under the new rules which
23 did a damage tolerance or crack growth approach,
24 considering a crack beginning anywhere in the
25 structure, even when the service history and the loads

1 didn't indicate it was likely to begin.

2 Again, we had to consider all the
3 alternatives through very extensive crack growth
4 studies and predict how long the structure would
5 survive under various scenarios. That led us into the
6 requirement for the SSID Program and more or less put
7 the 747 on the same basis as the newer models, 5-7 and
8 6-7.

9 So, that required combinations of visual
10 techniques, ultrasonic inspections and identified many
11 requirements on the airplane, and I think I covered
12 that pretty well in my discussion on the SSID Program.

13 So, as we -- so, that kind of covers that,
14 but in general, as we develop a structures problem in a
15 -- and identify some maintenance recommendation for it,
16 on any individual item we may provide recommendations
17 to the operator giving them thresholds, intervals,
18 guidance.

19 It may be fairly complex and it may be fairly
20 simple, depending on the structure, the access required
21 and what it takes to find the crack in the very early
22 stages.

23 DR. LOEB: Excuse me, Jim, for one second.
24 Mr. Vannoy, do you know what it was that led to the
25 change and to the damage tolerance concept, what

1 occurred that led to that?

2 WITNESS VANNOY: Well, I think it was a
3 combination of new technology and just trying to do a
4 better job in general. I think the CAA was
5 instrumental in pushing that, but within the industry
6 we developed the techniques to do the crack growth
7 analysis. We didn't have those methods in the 60's
8 and, so, it was a new concept.

9 But, the damage tolerance approach involves a
10 lot more work up front from the analysis side, but it
11 also incorporates those requirements into the
12 maintenance program so that for a particular piece of
13 structure you identify what the opportunities are to
14 find a crack, and you have to work the inspections of
15 your maintenance program to conform with that. So, you
16 will have those opportunities.

17 So, the airline working group is putting
18 together the maintenance planning for a model to have
19 the results of analytical information available to
20 them, and they have to develop the maintenance program
21 to give those opportunities to the operator. So, it
22 goes hand in hand for analysis, design and the
23 maintenance program.

24 DR. LOEB: Thank you. Jim, go ahead.

25 MR. WILDEY: Are you familiar with the

1 classification of fuselage skin as damage obvious or
2 amount function evident that was pre-Aloha era for the
3 purposes of doing the damage tolerance types of
4 inspections?

5 WITNESS VANNOY: On fuselage skin where we
6 considered the cracking would lead to depressurization
7 and what we call flapping of the skin?

8 MR. WILDEY: Yes.

9 WITNESS VANNOY: Yes, I am.

10 MR. WILDEY: I guess the question here would
11 be, after the Aloha accident it was obvious that this
12 classification was eliminated and the fuselage skin was
13 then incorporated into the SSID Program as far as it
14 being more -- it was then had to be inspected on a
15 routine basis.

16 Do you think that this type of philosophy at
17 this time seems warranted for systems types of things,
18 or where we have possible latent failures?

19 WITNESS VANNOY: I am certainly aware of the
20 change on the structures side that led to, you know,
21 putting more structure and putting skin laps into the
22 SSID Program. I am not sure that is a good analogy to
23 use on systems.

24 I think in my discussions I covered some of
25 the attributes of systems that they have, you know,

1 that are designed specifically for redundancy and to
2 annunciate a failure. The system design testing and
3 the certification we go through is supposed to
4 consider, you know, all the potential latent effects
5 that could exist on systems, and we did a very thorough
6 approach.

7 So, latent failures in systems is something
8 we basically can't tolerate and we -- when we identify
9 those items to further analysis, service history, or
10 whatever, we go in and eliminate them with a design
11 change and a Service Bulletin, and we have many
12 examples on the 747 where systems changes have been
13 implemented on airplanes as a mandatory -- you know,
14 because they were latent.

15 Now, I think the approach we are in today is
16 that we are going out and being more proactive and
17 looking for latent failures that we haven't seen
18 before, or haven't contemplated. I think, you know,
19 the Fuels Issues Task Group is doing that in the fuels
20 area to look in grounding and bonding which can be a
21 latent failure. We are taking steps in that area in
22 fuels.

23 The Gore Commission is pushing us towards
24 doing some similar studies in the aging wiring area to
25 potentially look for latent failures. I think Dr. Dunn

1 is actively involved with the FAA on those proposals,
2 working with Boeing. Maybe he could add some to my
3 comments here about what that program is going to do
4 specifically, looking for latent failures that we
5 haven't considered or found it for.

6 MR. WILDEY: This is a good opportunity for
7 Dr. Dunn. I know you are assigned to respond to the
8 Gore Commission's recommendations. Can you address
9 those?

10 WITNESS DUNN: Yes, I can. Actually, I am
11 the Project Manager for those activities within the
12 Aircraft Certification Service.

13 What we are doing is -- I believe it was
14 about February of this year that the White House
15 Commission on Safety and Security made a Recommendation
16 1-9 that the -- that aging aircraft systems be
17 incorporated into the Structural Aging Aircraft
18 Program, the one we have heard described previously.

19 So, the task that we have put together is to
20 address that recommendation, and the White House
21 Commission has expressed a concern in the general area
22 of aging systems, as well as the public. I have
23 received comments from various individuals expressing
24 their concern about aging aircraft systems, as well as
25 professionals in the field.

1 So, what we have done is we have put together
2 a program to -- we have put a program in place where in
3 June of next year, June 1998, we expect to have the
4 FAA's recommendations regarding aging aircraft systems
5 ready for the Administrator.

6 DR. LOEB: Do you contemplate a program along
7 the lines similar to or modelled after the SSIP Program
8 for structures for the systems area?

9 WITNESS DUNN: The intent is that by June of
10 next year that we will be in a position to make those
11 recommendations. What we are doing currently is just
12 going out, and we are going out into the field, and we
13 are looking at our processes to see if our processes
14 that we have in place regarding design approvals and
15 continuing airworthiness are adequate.

16 So, in that regard what we are doing is we
17 are going out and we are going to actually look at some
18 of the same fleet, aircraft that are in the current
19 Aging Aircraft Program.

20 CHAIRMAN HALL: Can I -- can I ask for a
21 clarification of one thing? When we talk about
22 systems, is a wire a system?

23 WITNESS DUNN: No, a wire is -- would not be
24 considered a system.

25 CHAIRMAN HALL: What about a wire bundle?

1 WITNESS DUNN: No, it would be -- a wire
2 bundle and wires --

3 CHAIRMAN HALL: What does Boeing consider the
4 150 miles of wire in a 747? Do you have a -- you know,
5 just wire, or is it part of a system, or --

6 WITNESS VANNOY: All wiring is parts. The
7 wire constitutes a part of the system material. It
8 supplies the energy or the indicating -- but, it is
9 part of a system.

10 CHAIRMAN HALL: It is part of the electrical
11 system of the airplane?

12 WITNESS VANNOY: That is correct.

13 CHAIRMAN HALL: No?

14 WITNESS DUNN: Well, no, not necessarily.

15 CHAIRMAN HALL: I just -- you know, if we are
16 looking at systems, I -- and we are talking about
17 wiring and we have got -- we have had some discussion
18 about wiring. I am trying to understand from a
19 layman's standpoint where does the wire fit into the
20 system?

21 WITNESS DUNN: Mr. Thomas, I think, can add
22 to this.

23 WITNESS THOMAS: Yeah, let me try a little,
24 Mr. Chairman.

25 CHAIRMAN HALL: Then I believe Dr. Dunn wants

1 to pop in, too, Mr. Thomas, but please proceed.

2 WITNESS THOMAS: I was just -- from my
3 viewpoint, the airplane has numerous systems on board.
4 They have hydraulic systems, fuel systems, electrical
5 systems, air conditioning systems.

6 We use a large percentage of this 150 miles
7 of wire to transfer energy and information around the
8 airplane. So, a given wire bundle, or a piece of a
9 wire bundle -- the FQIS one is the one we have used a
10 lot -- would be part of the FQIS system and therefore
11 part of the fuel system.

12 But, power, feeder lines, they come from the
13 engine or just part of the power systems, or any wire
14 on board the airplane is going to be considered to be
15 part of a system. So, when you talk system you
16 automatically include all the wiring in the airplane.

17 CHAIRMAN HALL: Where all those wires run
18 together that I described yesterday, and they are
19 bundled together, do you look at the impact of one
20 system on another, or in terms of failure?

21 MR. SWAIM: I think that would be a question
22 really for Mr. Taylor. Mr. Taylor is a specialist in
23 wiring and has been with Boeing for many years.

24 WITNESS TAYLOR: The answer to that question
25 is absolutely. Each system analysis takes into account

1 the fact that the wires in that system have been run in
2 a wire bundle with wires from another system, and if
3 there is any contention or feeling there can be
4 interplay between them that a separation of that
5 wire -- these wires for the system into another wire
6 bundle, the assignment of wires into wire bundles is a
7 result of a system analysis which makes sure that those
8 which need to be separated are separated.

9 There are various degrees of separation for
10 different kinds of threats which then allows the wires
11 to be put in a bundle where they will not be affected
12 by that threat.

13 CHAIRMAN HALL: And you do a -- one of those
14 fault tree analysis, or whatever we were talking about
15 yesterday?

16 WITNESS TAYLOR: Yes, systems analysis people
17 do them.

18 CHAIRMAN HALL: So, if you assume that the
19 wire was frayed or became corrosive or abrasive, you
20 would look at the impact of one wire?

21 WITNESS TAYLOR: Open circuit, a short
22 circuit, what would the impact of that be in the system
23 and the other wires in that bundle. If it would offend
24 any of them, then it is placed in another wire bundle
25 so that it will not have any affect on them.

1 I think if you think of your body, and as a
2 person you think of your veins and your arteries which
3 connect your various subsystems, the veins and the
4 arteries that are like the wire --

5 CHAIRMAN HALL: Well, I think, Mr. Taylor,
6 that is why most Americans are concerned about the
7 subject of aging aircraft, because they all have aging
8 systems. I know mine is. I have to -- it costs me a
9 lot more to maintain it now than it did.

10 So, I think that is why it is a concept the
11 American people can understand, and I think I just want
12 to -- I think what we are trying to grasp here is what
13 has been done about it in the past, and maybe what we
14 are doing and what has been done in the past is
15 adequate.

16 But, are there any things -- as we all know
17 that there is the fleet. The statistics show that we
18 are going to have older -- a larger number of the fleet
19 will be older airplanes. So, what is being done?

20 Mr. Vannoy did a very good job of laying out
21 what is being done in the structures area, and I guess
22 obviously now what is in systems. Do you think
23 additional things need to be done in wiring, or are you
24 looking at other things from a Boeing perspective?

25 Since you are the electrical and wiring

1 expert, as your fleet gets older are there other things
2 that you think would be -- you would recommend, or
3 would be -- Boeing would be looking at?

4 MR. TAYLOR: The answer to your first
5 question about do you think there are things that
6 should be done in wiring. It has been our philosophy
7 in Boeing that we should always be looking at the
8 wiring to see what we could do to make the wiring
9 better.

10 We understand that the wiring is not perfect.
11 We have done an enormous amount of research to try and
12 put the best wire that we can get onto the airplane,
13 but we also understand the fact that the airplane
14 environment may have some affect on the wire that we
15 haven't understood at that point in time.

16 So, we are continuously looking at wire
17 bundles in the aircraft to see how they are behaving,
18 what is happening, and then that is fed back so that
19 when we come to the design of the next airplane we take
20 that into account.

21 CHAIRMAN HALL: Thank you. I will let Dr.
22 Dunn comment, and then I will turn it back to Dr. Loeb.
23 I apologize.

24 WITNESS DUNN: Yeah, I -- the only thing I
25 can say is there are some -- there are regulatory

1 requirements which do -- which actually are given that
2 insist that the manufacturer look at the interactions
3 of systems. So, it relates to wire bundles where you
4 have more than one system in the same bundle wire, if
5 you will.

6 They are required -- there are regulatory
7 requirements to look at the interference and possibly
8 interactions and failures between those various
9 systems.

10 DR. LOEB: In developing this program that
11 you are looking at and developing now for aging
12 systems, is wiring going to be an inherent part of that
13 effort?

14 WITNESS DUNN: I am glad you asked, Dr. Loeb.
15 We are going to look at all systems, and all systems is
16 basically anything outside the primary structure which
17 was the focus of attention under the previous
18 Structural Aging Aircraft Program.

19 Systems would be things like pumps, valves,
20 wiring. Actually, I would refer to these more as
21 components, if you will. Tubing, landing gear,
22 engines; these are all considered in the context of the
23 study as systems.

24 DR. LOEB: So, it will include wiring?

25 WITNESS DUNN: Yes, most definitely.

1 DR. LOEB: Right, now -- and I think the
2 point I would -- I would like to explore a bit is the
3 kinds of things that Mr. Vannoy pointed out, and I
4 think it was the second to the last graph that you had
5 put up, the AD's, ESB's, all of the things that are
6 done when you find systems problems.

7 All of those things were done when we found
8 structures problems that pre-dated when -- before the
9 SSIP came into existence and then before the changes
10 that occurred after Aloha.

11 So, I recognize that there are programs to
12 address problems that arise in the systems area, but
13 there were also programs that were there to address
14 problems that arose structurally prior to the SSIP.

15 Nevertheless, at some point, because of
16 experience, because of history, it was determined that
17 a program specifically to address aging airplanes,
18 airplanes that were -- that were going to live beyond
19 their design service life was needed to be done, and
20 part of that program was to identify the critical
21 items, those items in which you could have a
22 catastrophic failure if they weren't addressed properly
23 and so forth.

24 I guess, Mr. Dunn, my question is, is this
25 what we are going to do in the systems area, something

1 similar to that? After Aloha, even though there was
2 this very excellent program, the SSIP Program that had
3 existed for many years prior to Aloha, that the FAA did
4 ask as a result of the task force and so forth for the
5 manufacturers to go back and re-evaluate all of the
6 structural components of the airplane, to re-examine
7 and determine whether new critical components needed to
8 be addressed and so forth, and there were a number of
9 AD's that resulted from that.

10 My question is, are we doing something like
11 that in the development of this program to address
12 aging systems?

13 WITNESS DUNN: What we are doing in order to
14 come to this plan that we want to put together by June
15 of next year, and a set of recommendations associated
16 with that plan, is to look at our processes, see if we
17 have adequate processes in place, look at the way we do
18 maintenance, look at the way we -- the tools our
19 maintenance people have, the training they have.

20 As we have mentioned earlier, we have a
21 continuing airworthiness program which is there to
22 address aging systems, if you will. However, we are
23 not sure that we have all the answers and that we -- we
24 want to make sure our processes are adequate, because
25 it relates specifically to an exact outline of a

1 program that you mentioned for the structural. We are
2 not there yet.

3 DR. LOEB: Yeah, my point is that there was
4 always a continuous airworthiness -- a continuing
5 airworthiness program that existed for structure.

6 WITNESS DUNN: We have had continuing
7 airworthiness programs, and you have to keep the
8 airplanes airworthy. Nevertheless, there was this
9 enormous development that went into this program that
10 addressed structure, and after Aloha combined corrosion
11 and fatigue.

12 We recognize there is a continuing
13 airworthiness program for systems. The question now is
14 these systems are -- as they age, we are learning some
15 things about them just like we learned about the
16 structure.

17 MR. SWAIM: Is that kind of learning process
18 that we went through in the structural area going to be
19 applied to systems, or are we just not going to learn
20 to use what we have already learned in the past?

21 WITNESS DUNN: Again, what we are going to do
22 is spend this year to look at it -- look at the scope
23 of our problem and our policies and procedures. At
24 that point, then we will decide whether a program akin
25 to the structural program is needed.

1 CHAIRMAN HALL: Okay, let's proceed, Mr.
2 Wildey.

3 MR. WILDEY: Yes, my thought at this time
4 would be to ask some of the other panel members if they
5 have any comments on this subject. Mr. Slenski, do you
6 have any insight you might add in terms of what the
7 military might be doing on this?

8 WITNESS SLENSKI: Well, there is two
9 approaches I can take here. I can talk generally, or
10 the presentation I did have was talking about wiring
11 failure mechanisms, and I will show you field failures
12 and how wire fails.

13 CHAIRMAN HALL: Well, why don't you give us
14 both approaches.

15 WITNESS SLENSKI: But, maybe we need to do
16 that first, if that is okay, because I think once I
17 show that, I think it will be a little more obvious in
18 my other comments. So, I guess we can get the first
19 slide up here.

20 (Slide shown.)

21 This basically was a request to discuss
22 wiring and cable failure mechanisms in aircraft, and
23 this was actually a presentation I did recently. Just
24 this, again, says where do we fit in this and how did
25 we get involved?

1 Basically, I am a failure analyst. I get the
2 components into the lab and we analyze it and provide
3 recommendations back to the users and operators of the
4 systems. So, first --

5 (Next slide shown.)

6 The next chart here we will get into more
7 detail. This is the -- what we call wiring the system.
8 We go out to procure an aircraft, we will have a trait
9 study done possibly on the type of wire insulation
10 selected, how the wiring is installed in the aircraft,
11 and I think at this point we do consider it to be a
12 system in itself because it has become so important,
13 and that now we do have fly-by-wire aircraft and the
14 wiring is a -- the failure of wiring in some situations
15 can affect the operation of the aircraft in flight.
16 So, it has become more of a critical system.

17 Take a look at the upper left there for a
18 moment (indicating). This is typical wiring in a
19 fighter aircraft. If you could zoom in on that?

20 (Next slide shown.)

21 As you can see, there is quite a bit of
22 wiring moving back and forth in there in that aircraft.
23 There is -- these bundles are almost like tree trunks
24 in the aircraft, and one of the problems of inspection
25 is every time you disturb that bundle you can induce

1 more damage.

2 That is -- a problem we run into is how much
3 inspection do you want to do on good wire, because in
4 the process of inspecting it you can cause more damage
5 in that process.

6 If we go to the lower right corner, this is
7 interesting. This is wiring out of an aircraft that
8 had been retired that is actually sitting in the desert
9 in Arizona. If we zoom in on that, this is one of the
10 problems with wiring.

11 (Next slide shown.)

12 Some of that wiring is actually saturated
13 with hydraulic fluid, so the wiring sometimes lives in
14 fairly severe environments. We talk about aging
15 problems and fluids. We do design wire to be exposed
16 to all types of fluids; hydraulic fluid, jet fuel,
17 water, and we do run tests to determine how long wires
18 can live or survive in these types of environments.

19 This is just an example of this. You do see
20 these types of fluids on wires, and they may exist for
21 quite a long time on the aircraft. So, that is how we
22 approach, as far as the Air Force.

23 We do consider the system and we do realize
24 wire is exposed to fluids. We actually have tests to
25 determine how long wires can last in these environments

1 when we make determinations for the aircraft.

2 Typically, the aircraft wiring age is tied to
3 the air frame, and when we replace wiring typically it
4 is more for upgrades. Avionics, or electronics in the
5 aircraft, as you are aware, change rapidly. Many times
6 we go in there and replace wire because of upgrades and
7 modifications.

8 DR. LOEB: Have you determined in these -- in
9 your looking at these issues at any time where wiring
10 was deteriorating in a shorter period of time than the
11 life of the airplane and made specific changes as a
12 result?

13 WITNESS SLENSKI: Yes, and I will show you
14 the example in the next slide on that. If we can have
15 the next slide, please?

16 (Next slide shown.)

17 Since we mentioned that, if we go to the
18 lower right corner. This is an example of wiring, and
19 this was due to chemical degradation that occurred
20 fairly prematurely in the life of this system.

21 Basically the wire was exposed to alkaline
22 materials, and these are basic solutions, and that
23 actually attacked the insulation and degraded its
24 mechanical properties, and we had cracking and arcing
25 from that situation.

1 That was -- basically, in this situation gun
2 gas is in the aircraft for getting near the wire,
3 forming potassium hydroxide, and that was attacking the
4 insulation which in this case was polyamide, and it is
5 a known problem that polyamides and high alkaline
6 cleaners and various compounds will degrade the
7 properties of that material. This is a situation where
8 we found that, and we have taken corrective actions.

9 If we could go up to the upper right
10 (indicating). I think this is an interesting example,
11 and this is an inspection. Actually, I was on some
12 aircraft where we found a broken wire-exposed conductor
13 during an inspection.

14 Typically, when we are looking at wiring and
15 you get into this inspection issue, most of your damage
16 is within about six to twelve inches of your connector,
17 and why that happens is because that is where most of
18 the maintenance is performed where you are moving large
19 boxes of avionics out, or you are moving the wire
20 bundles.

21 That is the type of wire that would see the
22 most of the damage, because most of our studies have
23 shown chaffing. Mechanical damage causes most of our
24 problems to our wiring.

25 What is interesting here to note is you have

1 got this exposed conductor there. However, that wire
2 is perfectly happy to sit there until there is a
3 mechanism to cause a leakage current and -- or a short.
4 To make that happen, another wire next to it has to
5 have an exposed conductor, or that exposed conductor
6 has to come in contact with the structure.

7 That can be intimate contact, or through a
8 conductive solution that may form between that wire and
9 another conductive surface. So, this is an example
10 where actually this wire could go until its life and
11 never have a problem, as long as another wire, or there
12 is an opportunity for a path to complete this
13 electrical circuit here.

14 DR. LOEB: So, that requires multiple
15 failures for something untoward to happen?

16 WITNESS SLENSKI: That is correct.

17 DR. LOEB: However, one of them, or two
18 failures, could be latent for a long period of time
19 resulting in only one failure at that point, creating a
20 problem?

21 WITNESS SLENSKI: That is correct, and that
22 is the difficulty, I think, as we -- say, developing
23 these aging programs, is when do you take action when
24 you are having these types of issues come up? But,
25 this is an example of the --

1 CHAIRMAN HALL: Mr. Slenski, does the Air
2 Force have a life span for a wire?

3 WITNESS SLENSKI: Currently, our life span of
4 wire is the air frame, but we do continuously monitor
5 wiring, look for -- what I would -- the word I think I
6 would like to use here is wiring integrity. We try to
7 maintain the wire integrity.

8 If that requires inspection programs, anti-
9 chaff programs, awareness -- because, again, a lot of
10 times the wiring problems we are seeing are chaff
11 related due to handling during maintenance or have
12 maybe even been during initial installation.

13 We try to make sure the people working on the
14 aircraft and maintenance troops are aware of wiring
15 problems, how the wire fails. They could look for
16 these types of damage sites during normal maintenance
17 of avionics.

18 Typically, again, you are not going to get in
19 there and disturb the wires. When you may see it,
20 though, is when you are removing other avionics for
21 either modification or repair. You need to go ahead
22 and look at the wiring at the same time to see if there
23 is any problem areas. So, we ask people to do an
24 overall inspection when they are in the area of the
25 aircraft.

1 DR. LOEB: But, right now the Air Force
2 treats wiring essentially like the commercial
3 counterpart, and that is for the aging -- for the life
4 of the airplane they assume the wiring will be okay?

5 WITNESS SLENSKI: In most cases, but the
6 reality is as we upgrade our systems we may actually
7 require -- actually replace complete wire bundles in a
8 system more for upgrade purposes than because we have a
9 degradation problem.

10 But, our instances where if we see a problem
11 we will actually replace the wire in the aircraft, and
12 there are programs like that going on today.

13 DR. LOEB: Mr. Slenski, what is an average
14 age for an Air Force airplane, or what do you consider
15 an older airplane?

16 WITNESS SLENSKI: That can be quite
17 considerable in age, but that is an interesting
18 question because the earlier photo I showed you was
19 from some of our fighters that have been retired with
20 around 7,000 hours of flight time, and they were
21 fifteen to twenty years old.

22 However, we have got cargo aircraft and
23 transport tankers that are well over thirty, forty
24 years old, obviously, in the fleet, such as B-52's.
25 That is a fairly old aircraft, and we are going to be

1 flying those aircraft for quite some time.

2 There are fairly aggressive programs, as we
3 have heard from Boeing, to maintain these systems and
4 look for reliability issues and upgrade the systems and
5 maintain all systems' bonding.

6 Maybe I can even answer one of the questions
7 yesterday. You asked about quality programs that we
8 instituted. After having discussion on the phone this
9 morning, where that came out of, we had some incidents
10 on the KC-135, some wiring related problems associated
11 with the fuel system.

12 As a result of that we now have phase
13 inspection of the wiring in that area, and we are
14 actually going in there checking bonding measurements
15 occasionally. There is a phase -- there is actually a
16 formal process for that now. So, depending on the
17 system, each system has its own unique requirements.

18 DR. LOEB: Okay, do you --

19 CHAIRMAN HALL: That KC-135, is that a Boeing
20 aircraft?

21 WITNESS SLENSKI: That is correct.

22 MR. SWAIM: Do you find your older transport,
23 or B-42's, or whatever, are they up in the same time
24 zone hours of flight as our higher time civilian
25 airplanes?

1 WITNESS SLENSKI: I don't think anywhere near
2 it. Obviously, the military flies different types of
3 missions, so we have no where near the flight hours on
4 our aircraft. Obviously, it is more the physical age.
5 Chronological age, I should say.

6 So, as an example, I was mentioning those
7 fighters only had 7,000 hours on them over a fifteen,
8 or twenty year period. That is actual flight hours, so
9 most of the life of a lot of the aircraft is sitting on
10 the ground, possibly in alert status.

11 MR. SWAIM: Sitting on the ground they go
12 through regular -- like block-up grades, and can you
13 explain maybe a little of the depot or block-up grade
14 type --

15 WITNESS SLENSKI: Every aircraft does have
16 phase inspections where I think, as Boeing pointed out
17 earlier, there is different inspection phases, and I am
18 not an expert in that area, but I do know we send --
19 there is maintenance done in the field and in -- every
20 so -- so many years and, again, it is system specific.

21 The aircraft will be sent back to a depot for
22 more major overhaul on all systems. I can't give you
23 that detail. I am sure I can find that information if
24 you need that, but it will be by per system, depending
25 on the type of aircraft.

1 CHAIRMAN HALL: Mr. Wildey, either Mr.
2 Taylor, or could Mr. Slenski address this subject of
3 what type of wire was on the accident aircraft and what
4 wiring is now used in commercial aviation?

5 MR. WILDEY: I think Mr. Taylor would be most
6 appropriate for that.

7 WITNESS TAYLOR: On the TWA accident
8 aircraft, the type of wiring was a wire commonly
9 referred to as polyex. It is -- and the Boeing
10 specification number for that is BMS-1342. BMS stands
11 for Boeing Materials Specification, and 13 indicates it
12 is an electrical material. That was the general
13 purpose wire used throughout the aircraft.

14 When you go into the design of a new
15 aircraft, one of the things you want to do is try and
16 select a general purpose wire which will be used as
17 much as possible throughout the aircraft and serve all
18 the needs of the majority of systems, and then the
19 special systems get special purpose wire.

20 The general purpose wire usually constitutes
21 about ninety percent of the wiring in the aircraft.
22 That wire is selected -- we go to that product to
23 select a wire which will meet the requirements of most
24 of the systems so that we minimize the differences in
25 processes that wire bundle assemblers and maintenance

1 people will have and, you know, reduce the number of
2 tools that they will have to have in order to make the
3 wire bundles and to service the aircraft.

4 The fewer processes they have to deal with,
5 the fewer changes of tools they have to do, the better
6 the job they will do and the more reliable will be the
7 wire harness. So, that is why we attempt to use one
8 wire type to satisfy the needs of all the systems.

9 CHAIRMAN HALL: Is that the same wire still
10 used on the 400 series?

11 WITNESS TAYLOR: No, the wire that we use in
12 the 400 series is a totally different wire. It has a
13 different chemical composition and it is a BMS-1348
14 which is a cross-link ethylene -- tetrafluoroethylene
15 insulation system, and we have had that wire on the 747
16 for many, many years now. It has been an excellent
17 performer.

18 CHAIRMAN HALL: Why did you change from the
19 polyex to that wire?

20 WITNESS TAYLOR: The reason we changed from
21 polyex was because the manufacturer of polyex stopped
22 manufacturing it. One of the polymers that were
23 necessary to make the insulation was no longer made and
24 they discontinued it.

25 MR. WILDEY: Mr. Slenski, I know that you

1 have a couple more view graphs to show me, and you will
2 be getting into types of damage to the different kinds
3 of wire. When we get to anything that can apply to
4 polyex, would you please point that out?

5 WITNESS SLENSKI: I will point that out to
6 you. If we can go back to the --

7 MR. WILDEY: Mr. Slenski, may I interrupt?
8 Before you continue, you mentioned that the Air Force
9 has a program to monitor the wire -- condition of the
10 wires. Could you -- is this just a visual inspection,
11 or what is the program to monitor the wires?

12 WITNESS SLENSKI: As I said, this time it is
13 pretty much a visual inspection, although there are
14 some attempts where you can electrically make
15 measurements if the aircraft is back at the depot where
16 you can actually disconnect a connector, you could put
17 a device on there to make leakage current measurements
18 to see if you have a short in a wire bundle at some
19 location. But, that typically would only be done at a
20 depot.

21 Now, we are looking at programs that we call
22 non-destructive inspection that allow us to find some
23 faults in wiring, and there are several programs out
24 there that are attempting to do this. I will discuss
25 one of those in a few moments here, and we can show a

1 chart on that on what we are actually trying to do with
2 wiring.

3 MR. WILDEY: Before we leave the view graph
4 that you have got up there now, though, this is a
5 defect in the insulation of the wire. The wire itself
6 is intact. Would something like this be detectable if
7 it wasn't visible to someone who just happened, maybe,
8 to see this?

9 WITNESS SLENSKI: This would not be because,
10 again, the wire -- as long as it is electrically
11 still -- there is integrity there as long as there is
12 no leakage current there, and obviously you have to be
13 able to see this and expect that it would have to be
14 exposed.

15 There are techniques out there, though, that
16 can find this type of damage, and I will show you an
17 example of that here in a few moments. They can
18 actually detect this type of a problem very easily.

19 MR. WILDEY: Thank you.

20 MR. SWAIM: Before we leave this, you
21 mentioned the Air Force has an anti-chaff program, and
22 my question is, is that the same as your on condition
23 maintenance?

24 WITNESS SLENSKI: It is a little bit
25 different. If you recall, one of the images I had

1 shown in a previous slide was off a fighter. In very
2 small airplanes, quite a bit of wire packed in those
3 aircraft. There is tight spaces. There is more
4 opportunity for chaffing and movement of wire bundles.

5 So, in our smaller aircraft we have more
6 aggressive anti-chaff programs than in a transport that
7 has much more space on it, so to speak, for wiring.

8 MR. SWAIM: Okay, so I would like to go back
9 to Mr. Taylor representing the manufacturer. The 7-4
10 is a big airplane, but it has got a lot of tight
11 spaces. Do you have an anti-chaff program set up for
12 the 747?

13 WITNESS TAYLOR: We do not have a program
14 that is specifically titled "anti-chaff." First of
15 all, we address the chaffing issue mainly in the
16 design. Chaffing begins in the design.

17 If you design the aircraft properly and you
18 make the wire bundles properly and you install them
19 properly, put clamps in the right places, put the right
20 kind of clamps in place with the right spacing, tie the
21 bundles correctly, then you will minimize the
22 opportunity for chaffing to occur.

23 So, that is the first area where we think
24 that the attention should be placed.

25 CHAIRMAN HALL: What is your service history,

1 Mr. Taylor, over the thirty years in regard to
2 chaffing? Is that -- have you found evidence of
3 chaffing being a problem?

4 WITNESS TAYLOR: We have had evidence of
5 chaffing. In fact, if you -- if one were to look at
6 the service letter that Mr. Vannoy referred to, we went
7 out and we looked at various 747's throughout the
8 world, inspected them.

9 We cited incidents of chaffing that had
10 occurred and we then put it into a service letter and
11 sent it to all the airlines with ample illustrations
12 showing what was occurring and giving them -- giving
13 them not instructions, but telling them what they
14 should be looking for and what they should do to
15 improve it.

16 We did have a chaffing problem on the 747-100
17 with polyex in the initial installation. The polyex
18 wire was the first wire where we had gone from
19 insulation systems like PVC, which are soft like boiled
20 spaghetti, and we went to polyex wire which is a thin
21 insulation for weight-saving -- one of the reasons we
22 did it was because of the constant pressure on all
23 systems people to minimize the weight of the system.

24 For weight saving purposes we went to a
25 smaller insulation system, a lighter insulation system,

1 and in order to get the same characteristics in the
2 life of the wire, it is a -- it is a tougher material.
3 It is harder, and initially when we changed over we
4 used the same installation techniques that we used for
5 the softer wire.

6 The polyex wire has -- I think a banjo string
7 may be a good analogue to the polyex wire versus the
8 softer wire. As a result, when we installed it we
9 didn't notice when we put it on, and when we put it on
10 in high vibration areas we did get chaffing. That
11 occurred after about 5,000 to 10,000 hours of service
12 life.

13 Immediately we got reports back from the
14 airline operators that we were getting a succession of
15 chaffing problems on the leading edge of the wing and
16 on the struts. We put together a program where we
17 analyzed what would happen and came up with a re-
18 design.

19 We put together kits. We sent out a Service
20 Bulletin to all the airlines alerting them to what was
21 going on. So, we had kits put together and sent them
22 the whole kit so that they could re-wire the -- re-wire
23 the airplanes.

24 Now, in these kits we used a different kind
25 of clamp. We changed the tie string spacing. We just

1 changed the installation so that we -- it was
2 compatible with the type of wiring that we were now
3 using. This was a learning experience which we and
4 others went through.

5 Once we learned that, then we incorporated it
6 in the wiring design from then on. So, we are
7 constantly improving the wire design so that we can
8 take care of changes in technology as they come along.

9 CHAIRMAN HALL: I assume that Service
10 Bulletin became an AD?

11 WITNESS TAYLOR: I don't know whether -- I
12 think the --

13 CHAIRMAN HALL: Dr. Dunn, do you know if --
14 or, Mr. Crow, whether that --

15 MR. SWAIM: I am aware of a chaffing AD that
16 we had on some of the fuel system wiring.

17 CHAIRMAN HALL: Well, if we could find out
18 and provide that for the record, I would appreciate it.

19 WITNESS TAYLOR: This was nothing to do with
20 fuel service -- fuel system wiring. This was totally
21 and distinctly complete from fuel system wire. So,
22 that is really the only chaffing problem we have had
23 that does not occur in a random type of pattern.

24 MR. RODRIGUES: Mr. Chairman, from the Boeing
25 table?

1 CHAIRMAN HALL: Yes, sir.

2 MR. HUGHES: That Service Bulletin was not an
3 AD.

4 CHAIRMAN HALL: It was not an AD?

5 MR. HUGHES: Correct.

6 CHAIRMAN HALL: Okay, thank you. Well, that
7 is a very complete answer, Mr. Taylor, and one that was
8 well understood. Thank you.

9 DR. LOEB: Before you -- just one additional
10 question on the polyex, Mr. Taylor. Have you in your
11 experience with polyex found other problems, other than
12 this chaffing problem due to the vibration?

13 WITNESS TAYLOR: We have found that polyex
14 has two other attributes that we preferred it not to
15 have. One of them is the polyex wire is constructed --
16 it has a three-layers of material. The inner layer is
17 about five thousandths of an inch thick of polyex
18 material.

19 Then there is another layer about the same
20 thickness, and then there is an outer layer which we
21 call a top coat. It is white, and one of its purposes
22 is so that we can put a mark on it that -- so that
23 people can identify that wire bundle.

24 It is a unique wire for that -- sorry -- a
25 unique mark for that wire. Every wire on the airplane

1 has a unique identifier, and that is one of the
2 purposes of that white top coat. We have found over
3 the years that that top coat tends to separate from the
4 outer layer and you get flaking occurring. That is one
5 problem.

6 DR. LOEB: Is that because, you say, of the
7 marking process?

8 WITNESS TAYLOR: It has nothing to do with
9 the marking process. It is an adhesion problem between
10 the top coat and the outer layer, and through time the
11 adhesion -- it separates. That occurs randomly. It
12 does not occur in large flakes, or anything like that.
13 It is just randomly.

14 The second problem we have had is we have
15 seen occurrences of cracks, radial cracks. If you were
16 to take something like that and bend it (demonstrating),
17 you would see a crack across it. We have seen
18 occurrences of that. That, again, occurs on a random
19 basis. It usually occurs in a place where there is a
20 bend radius.

21 We try our best to utilize the space as best
22 we can and make them -- keep the bend radius to a
23 maximum and not to a minimum. We try not to just stuff
24 it in there, but organize it so we that we use the best
25 bend radius.

1 We have also seen it in some places where it
2 is disconnected. The connector has been used to
3 disconnect from equipment which is removed readily, or
4 often just at the back of the connector.

5 DR. LOEB: These cracks are just through the
6 top layer, or --

7 WITNESS TAYLOR: The cracks, depending on the
8 amount of stress that has been put on them, can go
9 through just that top coat. It can penetrate the outer
10 coat, and sometimes there is evidence that they have
11 penetrated the inner coat.

12 The design of the wire with the two layers of
13 it is specifically designed so that if you stress the
14 outer layer and it does crack, the crack will not
15 propagate into the second layer. You will always have
16 an insulation system.

17 The other thing about these cracks is that
18 they -- even although the crack is there, they are very
19 close. They are as close as my fingers together so
20 that when they are in the aircraft, even though the
21 wire is cracked there is no exposure of the conductor
22 to a fragment of metal, or to any other piece of
23 structure.

24 DR. LOEB: What about at bends, though? Have
25 you found any of these cracks at bends where the wire

1 is stressed where the insulators are --

2 WITNESS TAYLOR: I have not seen any like
3 that. I have inspected 747's, I have looked at the
4 leading edges of the wings which is a pretty severe
5 environment, and the -- I saw on one airplane one crack
6 just at the back of the connector.

7 It so happens this airplane was in service,
8 and I was not about to disconnect that connector to
9 detect whether or not the crack actually --

10 DR. LOEB: Is this cracking phenomenon in any
11 way associated with aging, or just -- well, you know.

12 WITNESS TAYLOR: The cracking is associated
13 with aging in a specific environment. If you have a
14 humid -- not a humid, but an environment where you have
15 a high Ph type of fluid and a tight bend radius,
16 eventually the fluid will contribute to the cracking by
17 the effect of hydrolysis as to loosen the bond between
18 the molecules, and then eventually a crack will appear.

19 But, as I say, the crack is a line and not a
20 gap.

21 DR. LOEB: Does your experience with a VMS-
22 1348 show that it is a superior wiring to the polyex?

23 WITNESS TAYLOR: In terms of aging, it does
24 not have any of the characteristics of the polyex. It
25 does not have a top coat on it, for example. It has

1 two layers, the same idea, so that any stresses on the
2 outside will not be transferred into the inner layer.

3 The cross link tepsel is impervious to fluids
4 and, so, we don't have this problem of hydrolytic
5 attack by fluids. So, it is a better performer. It is
6 an excellent wire.

7 CHAIRMAN HALL: Mr. Taylor, could I ask --
8 and let me be sure -- my understanding is on the
9 accident aircraft that the polyex wire was used in wire
10 runs adjacent to the center wing tank fuel quantity
11 indication system wiring, and that polyex was used for
12 the fuel pump wiring.

13 Did you do a failure analysis on that system?

14 WITNESS TAYLOR: I have not been involved in
15 any of the failure analysis conducted on the TWA
16 airplane.

17 CHAIRMAN HALL: Are you -- in your history
18 with Boeing, are significant wiring bundle maintenance
19 failures copied so they are reported to Boeing by the
20 airlines and come up through the system that was
21 described to us yesterday?

22 WITNESS TAYLOR: Yes, the wiring failures are
23 reported. The most significant -- the effect of the
24 failure, the more rapidly the failure is reported and
25 the more rapidly something is done about it, as Mr.

1 Vannoy described.

2 Usually what happens is that when a wiring
3 failure is reported, it is also reported back into our
4 standards organization, and we will look at it and if
5 we recognize it as being of a pattern we have seen
6 before, we will add that to the list and we will
7 already have done something to solve that problem.

8 If it is a new problem, the first thing we
9 will do is ask the airline to send that particular
10 piece of damaged wire to us so that we can make an
11 analysis of it and then do something about corrective
12 action if we need to do it.

13 One of the major problems is that if wire
14 damage is discovered on an airplane which is in
15 service, the necessity to get that airplane back in
16 service overrides the attention of the mechanic to
17 carefully store the wire and preserve the evidence so
18 that he can send it -- he or she can send it back to
19 us.

20 So, in many cases, we do not get the wire
21 back and, so, we are unable to really do a proper
22 failure analysis. But, in many cases we do.

23 CHAIRMAN HALL: I guess that leads me to the
24 question, Dr. Dunn, in looking at the White House
25 Commission's recommendation, are you going to be

1 looking -- going out and physically inspecting the
2 airplanes, or just looking at records?

3 WITNESS DUNN: No, sir. We are going to go
4 out and physically look at the aircraft. We have
5 systems engineers who will be accompanying us as well
6 as maintenance personnel and research people within the
7 FAA, as well as possibly, depending upon the area of
8 interest, industry experts to help assist us in looking
9 at the systems in the aircraft.

10 CHAIRMAN HALL: Thank you. Mr. Swaim? Oh, I
11 am sorry, Mr. Crow and Mr. Slenski, you have comments?
12 I am sorry.

13 WITNESS CROW: Yes, sir. For the record I
14 would like to share some information that may be
15 helpful to the Board. It may be helpful to the
16 American people in understanding that there are two
17 processes that are at work in the design and the
18 operation of an aircraft.

19 One of them is the design criteria, and at
20 the present time, as I have listened to our
21 distinguished witnesses and others that have given
22 testimony, most of the testimony that I have heard thus
23 today is regarding design criteria and not continuous
24 airworthiness requirements.

25 One of the things that I would like to offer

1 to the Board for a full understanding of some of the
2 problems that you are very interested in -- and we are
3 in Flight Standards very interested in this also --
4 wiring; some of the largest concerns that we have in
5 wiring are the events that occur during routine
6 maintenance and the changing and modification of
7 aircraft.

8 I would suggest to you, not as a Flight
9 Standards opinion, but it is my opinion that most of
10 the problems that we have regarding wiring are the
11 results of two things, aging and foreign object
12 intrusion such as hydraulic fuels, et cetera.

13 But, one of the other most probable causes of
14 damage to wiring is the maintenance activity that does
15 occur around them. One of the initiatives that we have
16 in Flight Standards right now, as we speak we have a
17 lot of the carriers that are installing smoke detection
18 and fire suppression equipment in the cargo
19 compartments.

20 One of the initiatives that we have in
21 particular is standing side by side with our
22 certificate holders watching the prototypes of those
23 things going in, and one specific area of observation
24 and concern is when we are working in close proximity
25 to an existing wire bundle to make sure that those

1 things do not have contraindications, one on another,
2 and cause a chaffing concern.

3 Over the years -- and I share some experience
4 with these other gentlemen. In forty years of aircraft
5 maintenance in various levels of responsibility, I have
6 noted often that it is the modification of aircraft and
7 the maintenance of aircraft after the aircraft is
8 delivered to the certificate holder, or to the Air
9 Force in this case, that the damage to the wiring
10 occurs as a routine thing, concomitant and existent
11 with the maintenance activities in the modification of
12 the airplane.

13 So, I would suggest from a Flight Standards
14 perspective that we spend an awful lot of time, as we
15 are doing currently, looking at those modifications and
16 looking at those things that do disrupt the wire
17 bundles going through the airplanes. Thank you, sir.

18 CHAIRMAN HALL: Thank you. Mr. Craycraft,
19 you have forty-one years of experience. What has been
20 TWA's experience with polyex and the wiring of the 747?
21 Do you have anything you would want to share with us?
22 I assume -- you have been a hands-on person, right?

23 WITNESS CRAYCRAFT: Yes, sir.

24 CHAIRMAN HALL: Yeah.

25 WITNESS CRAYCRAFT: The wiring on the 747 on

1 the TWA fleet has not really been a continuing problem
2 area. The odd time we would have an individual system
3 that will have a chaffed wire, and oftentimes that is
4 because of a broken clamp or something of that sort,
5 that will allow a wire bundle to sag against structure
6 and chaff.

7 The result there is either you get a false
8 indication of a light in the cockpit, or a system will
9 not work, or you will pop the circuit breaker,
10 depending upon the extent to which the wire is
11 contacting the structure.

12 Again, I say that has been most rare as far
13 as the 747 is concerned, that we have not had the
14 problems with the polyex wire. Our earlier airplanes
15 were wired with a wire that was preceding polyex and
16 some of the -- some of our aircraft do have the polyex.

17 I was with the NTSB team when we were at NASA
18 Labs, and we observed some cracking of the insulation
19 on the -- some of the wiring that was brought there.
20 None of this was wiring that was in the fuel quantity
21 system. That is an entirely different type of wire
22 that is being used in the FQIS wiring.

23 So, any of the problems we are describing
24 here do not relate to that in any way, shape, or form.

25 CHAIRMAN HALL: Could you tell us -- or, Mr.

1 Taylor tell us about the wire in the FQIS system so we
2 know the difference.

3 WITNESS CRAYCRAFT: I will defer that to Mr.
4 Taylor, since he is the wire expert.

5 DR. LOEB: Well, before you do, I would just
6 like -- some of that polyex wire is routed, though,
7 along with FQIS wiring; is that correct? I mean, FQIS
8 wiring is routed in places in common with -- in the
9 same wire bundles as polyex?

10 WITNESS CRAYCRAFT: There are some locations
11 where they are in a common bundle, and there are other
12 locations where the fuel quantity wiring is routed in a
13 separate clamp away from the other bundles.

14 DR. LOEB: Right, thank you.

15 WITNESS CRAYCRAFT: But, what we received
16 there at NASA Labs was a ball of wire wrapped up in a
17 box, so who knows what was bundled next to what. But,
18 none of the wire that we examined there showed any
19 evidence whatsoever of arcing.

20 There was some cracking, but as Alex had
21 described, the crack was just a minute crack
22 circumferentially around the wire, and you had no loss
23 of protection of that wire.

24 CHAIRMAN HALL: Thank you. Mr. Taylor, if
25 you could explain the difference to us, and then we

1 will go back to the Technical Panel, since --

2 WITNESS TAYLOR: Well, actually, this picture
3 behind me illustrates the type of wire that is in the
4 FQIS system. The conductors are -- the conductors you
5 see in the center are copper, they are silver plated.

6 The outside insulation you see is teflon, and
7 teflon is -- you all know how well teflon does as a
8 bearing surface, et cetera, et cetera. So, it is a
9 very, very good insulator, it is extremely resistant to
10 any kind of fluids and it is flexible, and it just
11 makes a good wire.

12 The thickness of that insulation is fifteen
13 thousandths of an inch. The size of the conductor, the
14 overall gage size is twenty gage. Now, the -- that is
15 a basic wire.

16 The FQIS wiring system consists of a cable
17 which contains one or more of these wires. The type of
18 system we were talking about yesterday usually has one
19 single wire with a shield, a metal shelf over the top,
20 a braided shield over the top of it, and then it can
21 come -- and it is usually white. It then can come with
22 one other wire in that harness which is red, or it can
23 be blue, depending on the system design.

24 That, then, has an over-braid of a lacquered
25 nylon which holds the whole thing together, and it

1 makes a very substantial bundle.

2 CHAIRMAN HALL: Does teflon have an economic
3 design life?

4 WITNESS TAYLOR: No. Let me rephrase that.
5 I am talking fifty years, I am not talking two
6 centuries or three centuries away from here. I am
7 talking just within the realm of my lifetime, another
8 fifty years.

9 CHAIRMAN HALL: All right. Thank you, Mr.
10 Taylor. Mr. Swaim, are you or Mr. Wildey up?

11 MR. SWAIM: Today I will be Mr. Swaim. Mr.
12 Slenski, I would like to go to you for just a second.
13 We have been talking about small radial cracks and
14 wiring. We have heard about this a couple times,
15 cracks that go around the wire, possibly down to the
16 conductor.

17 If it goes down to the conductor, but you
18 can't see the conductor, is that okay, or is that ever
19 a problem to have the conductor in that condition,
20 especially -- excuse me, let me throw in one more part
21 of that question.

22 We have found water based cleaning fluid
23 residues in wiring areas in this airplane, so -- I am
24 sorry, go ahead.

25 WITNESS SLENSKI: Once you have started a

1 crack -- and this is referring to polyex now, or any
2 insulation?

3 MR. SWAIM: Primarily in this accident
4 polyex, but I would like more general.

5 WITNESS SLENSKI: I am not sure if I could
6 speak. I don't know personally many of the properties
7 of polyex, but as far as any insulation, once you have
8 initiated a crack, there is always that potential that
9 you can crack all the way through.

10 Now, it is typical with these insulations
11 there is enough dielectric strength to withstand the
12 voltage applied to them. As long as you have any
13 insulation there at all you are probably not going to
14 violate it. You actually have to get all the way down
15 to the conductor, most likely, to actually have some
16 type of arc event.

17 So, even if we got down to maybe even the
18 inner third layer, as long as that has integrity you
19 probably will be okay, but obviously any bit of flexing
20 could take that further on down into the -- and expose
21 the conductor.

22 We heard the explanation of three-layer
23 construction for the idea that you will not propagate
24 the crack through each layer, but if you have a bend in
25 that insulation you do have stresses in those areas.

1 You can stretch these materials and they can initiate
2 cracks.

3 So, you know, once you have initiated cracks
4 in there it is undesirable, but detectable. You are
5 only going to see that again if you have an arc event,
6 or visually you might see it, but it can be very
7 difficult.

8 MR. SWAIM: But, if you do have this crack
9 that goes all the way through and you have got a humid
10 environment --

11 WITNESS SLENSKI: But, if you have conductive
12 fluids, you know, you would almost have to have the
13 conductive fluid in there, as Mr. Taylor was
14 mentioning. Even if it is a fine crack, if you have
15 fluids in there they can get down into that crack and
16 you can set up what we call arc tracking, eventual wet
17 arc tracking, where the fluid develops a conductive
18 path between two surfaces, and over time you can
19 actually initiate an arcing event.

20 So, you need the conductive path in there
21 somehow, and that could be a pieces of metal, it could
22 be a fod, a piece of metal fiber, or a piece of -- a
23 small piece of metal, or it could be the conductive
24 solutions which we recognize are on all aircraft.

25 MR. SWAIM: Okay.

1 DR. LOEB: Let me just follow up a bit on
2 that. Does the Air Force use polyex in its airplanes?

3 WITNESS SLENSKI: I am not aware of polyex
4 being used in any Air Force aircraft. I think it has
5 been used on some military aircraft, but I am not aware
6 of it on Air Force aircraft in general.

7 DR. LOEB: But, you do have Boeing -- Boeing
8 Aircraft --

9 WITNESS SLENSKI: That's true, so I guess it
10 is possible, then.

11 DR. LOEB: But, in general you are not
12 aware -- in general, what kind of wiring is used?

13 WITNESS SLENSKI: Well, there are several
14 types in there. As we have seen, teflon is one of the
15 insulations. One of the insulations is 81-381, or
16 polyamide insulation. That is also known as a trade
17 name by Kapton, as an example. That is used
18 extensively on aircraft.

19 Mr. Taylor mentioned the cross link tepsel.
20 That is an insulation. We have some newer insulations
21 out there today we refer to as hybrids, and that is a
22 combination of a teflon with a polyamide insulation,
23 and there are some older insulations out there, too.

24 So, there is quite a family of insulations
25 out there. All of these insulations meet aerospace

1 requirements. Obviously, there is -- over the years we
2 have learned some deficiencies in these materials, and
3 when we do that, we do take some action to minimize
4 those types of problems.

5 DR. LOEB: Have you run into problems with
6 arc tracking in any of your wiring?

7 WITNESS SLENSKI: There have been arc
8 tracking events. I think any insulation can suffer
9 what we call an arc track event. Mr. Taylor, I think,
10 referred to this, too. All our insulations we are
11 using today are very thin wall insulations for weight
12 savings, as we recognize there is quite a bit of wire
13 on an airplane.

14 150 miles of wire, if we can reduce the
15 thickness of that insulation, especially when you are
16 in the twenty gage range, the insulation is a
17 contributor to the weight and volume of the insulation.
18 It is significant.

19 So, we have designed down the size and volume
20 and weight to save for aircraft design purposes. But,
21 these insulations, because of that -- I think we have
22 taken that into account.

23 Also, I would like to follow up what Mr.
24 Taylor had mentioned; you know, for anti-chaffing the
25 best solution is in your initial design, and we go to

1 great lengths. I mean, we have government committees,
2 which I am on, and also industry. There is the Society
3 of Aerospace Engineers.

4 We had talked about installation, and we do
5 have rules that we have and guidance on how do you
6 install wiring. As Mr. Crow mentioned here, too, there
7 is issues with maintenance induced chaffing, and that
8 is something we are aware of, also.

9 DR. LOEB: Let's get back to arc tracking for
10 just one minute. Is that a kind of an aging problem?

11 WITNESS SLENSKI: Well, I can show you an
12 example of an arc tracking even because it is in my
13 presentation. So, maybe we can get --

14 DR. LOEB: In fact, maybe we want to let you
15 finish your presentation.

16 WITNESS SLENSKI: I am going to get to that
17 in just a moment. If we go to the next chart.

18 (Next slide shown.)

19 I think I am going to skip -- let's see what
20 the next chart is you have here for us.

21 (Next chart shown.)

22 Okay, this was an actual example of aging,
23 but this is a little bit different situation. This is
24 where the conductor is causing us a problem where we
25 have a -- if we go up to the upper left corner

1 (indicating), and, again, we mentioned wiring the
2 system and we concentrated quite heavily on the
3 insulation. You also have to worry about the connector
4 and the conductor also as an issue.

5 In this case, what we are looking at here is
6 the resistance increase in the crimp joint, and if you
7 could point -- there is one of those crimps that is
8 somewhat removed down in there. If you could point to
9 that? Right there (indicating).

10 That actually caught fire, and what was
11 happening here is there was over a hundred amps of
12 current going through that connection, and we had
13 resistance drop across there. If you think about a
14 resistor, if you have current going through that
15 resistor you create heat.

16 We try to keep these connections at very low
17 resistance. As that resistance increases, the heat is
18 dissipated through the connection. In this case, it
19 actually caught fire because it got so hot, and this
20 was an actual failure mechanism related to the plating
21 on the wiring over very many years of use and high
22 temperatures. It actually degraded and eventually
23 caught fire. So, this is just another aging issue you
24 can deal with with wiring.

25 DR. LOEB: What kind of wiring was it?

1 WITNESS SLENSKI: This actually was teflon
2 based insulation with a mineral fill material in it.
3 So, the wiring insulation itself was not so much the
4 contributor here, it was the actual interconnection
5 that caused the failure.

6 You know, again, this is an example of
7 failure analysis and that -- fortunately, in this case,
8 this was just an incident in the aircraft. There was
9 no loss of the aircraft, and Mr. Taylor mentioned it is
10 always nice to get these exhibits back to a lab.

11 In this case, our maintenance was concerned
12 about it. They removed that cable in there and got it
13 back to our lab so we could understand what happened,
14 and then we were able to take corrective action. That
15 is, again, important to -- when you have failures, to
16 identify the cause and then get some type of process in
17 there to take corrective action.

18 If we could just go to the next slide,
19 because I think this is -- the next one might be
20 interesting.

21 (Next slide shown.)

22 Let's go to the upper left first
23 (indicating). This is an example of a -- this is a
24 mishap of one of our aircraft. Fortunately, we had a
25 fire in the rear of the aircraft and it actually

1 developed while the aircraft was in landing
2 configuration.

3 The airplane was able to get on the ground so
4 that it was -- although there was damage to the
5 structure of the aircraft, the aircraft landed
6 without -- safely. So, what we are looking at is the
7 fire damage, and if we could go to the lower image in
8 the center there (indicating), that is the hole that
9 was left from the fire, and we have actually burnt --
10 melted aluminum, as you can see.

11 Now if we go up to the upper right
12 (indicating), this is inside there, and what we are
13 looking at is remains of the wiring, and I think you
14 can possibly point to some of those. It is a little
15 above that arrow (indicating).

16 There was an extensive fire in here, and
17 basically what happened is the wiring had chaffed
18 against an aluminum hydraulic line. The hydraulic
19 fluid is high pressure, so we had misting in there, and
20 with the arcing there was ignition in there, and that
21 is what caused this event.

22 To show that, if we could go to the next
23 chart we will actually look at the hydraulic line.

24 (Next slide shown.)

25 The hydraulic line is in the upper left

1 corner (indicating). What is interesting is that this
2 incident -- and this is what we get into in, I think,
3 mishap investigations -- if this incident had occurred
4 at high altitude and the aircraft had actually impacted
5 the ground, the possibility of recovering this type of
6 hardware would have been very difficult to come back
7 and find this type of evidence because, as I think I
8 have mentioned, especially in electrical systems, they
9 typically are damaged during post-mishap fires.

10 Typically they are low temperature materials,
11 or organic materials. They don't survive well in the
12 accident. So, it is very difficult to reconstruct what
13 actually occurred when you are dealing with electrical
14 systems.

15 If we go to the center -- lower (indicating).
16 That is the actual pitting that occurred in the
17 aluminum hydraulic line where we had spewing of the
18 fluid, and that is the actual erosion that occurred,
19 probably over time in the aircraft. It eventually
20 eroded through the wall of that tube.

21 Now if we go up to the upper right
22 (indicating). After this event occurred -- and, again,
23 we understood what had happened. We go out and look at
24 other aircraft, and this is that same hydraulic line,
25 and we can see wires actually up against that line.

1 This was the chaff problem we were dealing
2 with here. So, the solution here was to re-route those
3 wires. So, we were dealing with a maintenance issue
4 here that caused this failure.

5 MR. SWAIM: I would just like to note that
6 the NTSB right now is investigating, or putting
7 together a report on hydraulic line and wire chaffing.
8 I believe that the original or the crux that led to
9 that was in a Citation Jet, a corporate jet, and I was
10 just digging through a pile of paper. We have gotten
11 an lot of correspondence from people in the public.

12 This one is from a Mr. Jereky (sic) in
13 Monroeville. It is exactly the same thing, electrical
14 wiring, chaffing on a hydraulic line leading to a
15 landing gear bay fire which we talked about yesterday.
16 This one was in 1940-something. So, it is not a new
17 problem.

18 WITNESS SLENSKI: As an example, well, what
19 have we done to eliminate the problem? We went back to
20 the lab and we have done some arc erosion tests on
21 hydraulic lines to see if aluminum -- typically we use
22 stainless steel lines. We don't use aluminum anymore.
23 This was an old aircraft type.

24 But, we have done some tests of how long can
25 you arc before you actually expose the wall of the

1 hydraulic line, and that is some of the research we
2 have been trying to disseminate to industry.

3 WITNESS TAYLOR: Mr. Chairman, I would like
4 to add something. We have one hundred forty-seven 747
5 wires which have airplanes which are wired with the
6 polyex wire. We have no record of any incident of arc
7 tracking taking place on any of the wires on any of
8 these airplanes.

9 I just wanted to make sure that that goes
10 into the record since we have been talking about arc
11 tracking, that we have not any evidence on any 747
12 airplane of arc tracking of polyex wire.

13 CHAIRMAN HALL: Mr. Craycraft?

14 WITNESS CRAYCRAFT: May I add to that that
15 TWA has had no experience whatsoever of arc tracking of
16 this wire on a 747.

17 CHAIRMAN HALL: Okay, thank you.

18 WITNESS SLENSKI: In follow up to that
19 previous incident I had shown you, these are rare
20 events. They obviously are not occurring everyday.
21 The same with the Air Force; we do have arc track
22 events that have occurred over the years. It is not --
23 again, we don't have polyex, and it is going to be the
24 next slide that we will talk about arc track event.

25 (Next slide shown.)

1 This is an example, if we go to the lower
2 left of a wire bundle. This is a polyamide insulation.
3 Again, also identify the trade name Kapton. This is an
4 example of an arc track event that came out of an
5 aircraft basically initiated by a chaffing event.

6 If we go up to the center where we will get a
7 close up of the damage (indicating), and now I think if
8 we go up to the upper -- where we actually see what is
9 happening here, and this insulation, polyamide, is
10 unique, and it is a tape-wrapped insulation. It is not
11 estreated on the wire as we were seeing previously in
12 the teflon. It is actually wrapped on the insulation.

13 It is unique in that the material does not
14 have a melting point. At high temperatures it
15 carbonizes. That is the evidence -- that is the issue
16 here with arc tracking.

17 This particular material, if you do develop
18 and arcing event -- and of course you have to somehow
19 violate the insulation and expose the conductor -- you
20 can carbonize that area which is conductive enough to
21 sustain arcing, and you can get what we call the arc
22 track event.

23 It is rare. It has occurred on some
24 aircraft. I personally am not aware of us losing an
25 aircraft due to an arc track event. It has happened.

1 DR. LOEB: Have you encountered arc tracking
2 on any wiring other than Kapton?

3 WITNESS SLENSKI: I am going to show you an
4 example of one in just a moment of another insulation
5 type. Any insulation -- and many of us in the industry
6 have been running tests on Kapton insulation. Mr.
7 Taylor has run quite a few on 81-381, or polyamide
8 insulations.

9 All insulations in certain configurations can
10 be forced to arc track, basically. If you put
11 conductive solutions on there, vary voltages, you can
12 get these events to occur. Any -- these are all
13 polymeric materials, and they do have carbon in the
14 chain of the materials, which is conductive if you can
15 get it to form on the surface, or if you have another
16 fluid that is carbonaceous we can actually initiate
17 these types of events.

18 What we are really looking at here is arcing
19 over time, and it is thermal damage through the arcing
20 process. It damages adjacent wires which can
21 propagate, and we do have circuit breakers that
22 eventually will stop these reactions, but they
23 encourage such a quick event that circuit breakers
24 sometimes will not react fast enough to these
25 processes.

1 If we go to the next slide.

2 (Next slide shown.)

3 I know there was some interest in hot stamp
4 marking. This is a field failure of hot stamp marking
5 and wiring that is on polyalkine insulation. It is a
6 very -- it is an older insulation.

7 In this case here, your hot stamp process
8 penetrated the insulation, conductive fluids were near
9 this area and this was 115 volt three-phase power and
10 we had arcing between the various wires in different
11 phases, and that led to this failure.

12 I think if we go to the lower quadrant, that
13 is an actual area where it was hot stamped at one time.
14 Again, as I mentioned I believe yesterday, hot stamping
15 is an acceptable process for wiring when it is
16 controlled. You just have to be somewhat careful in
17 that marking process. This is an example. This we
18 call wet arc tracking because there was a fluid
19 involved and, so, this was not dry arc tracking.

20 Then, the final slide.

21 (Next slide shown.)

22 I think this was discussed previously. This
23 is a program -- again, if we go up to the lower left --
24 or, upper left (indicating). We have talked about are
25 there any ways to predict the life of our wiring, or

1 evaluate its integrity, and this is just an example of
2 wiring in an aircraft.

3 We have looked at some non-destructive
4 techniques that can allow us to possibly find defects
5 in wiring, and if we now move over to the upper right
6 (indicating) this is an infrared technology here we are
7 using.

8 This technique under certain conditions can
9 actually detect breaks in insulations, or flaws in the
10 insulation. We have a program now trying to determine
11 if this can be used to inspect wiring and, again, this
12 would be helpful in finding chaff damage or mechanical
13 damage to the wire.

14 So, there are other programs. Some of these
15 are just some examples of how you can do this. There
16 are other programs out there that are actually removing
17 wire from aircraft and running some tests to predict
18 the age of the wiring. So, there are actually several
19 programs out there trying to develop a program for
20 evaluating the aging or the integrity of the wire.

21 The last slide is just a summary here.

22 (Next slide shown.)

23 I really did not prepare to get into other
24 components other than wiring. The general statement
25 here when it comes to electronics -- and we discussed

1 this a little bit -- but, what my experience has been
2 is that it is the electronic systems that are what I
3 call electromechanical in nature that we seem to have
4 the most problems with aging. That is the wiring, the
5 connectors, solder joint switches.

6 Anything that moves over time can experience
7 some type of degradation. So, these are the areas that
8 we have been concentrating on when it comes to aging of
9 electronics.

10 DR. LOEB: Is the intention to develop a
11 program specific to aging wiring?

12 WITNESS SLENSKI: There is an attempt, and I
13 was giving you an example of trying to assess the
14 wiring age issues. We are looking at the possibility
15 of that. Again, it is more of a broad umbrella when we
16 are talking about aging of electronics and structures
17 where we are looking at all these types of components.

18 I think what I tried to do at the next bullet
19 there was try and give you -- this is my opinion about
20 if we are going to look at these issues what we have to
21 do.

22 First of all, you have to verify your
23 failure, and that is usually through -- what I usually
24 do is physics of failure actually determine cause of
25 failure. Relate that to design, materials and

1 manufacturing process, come up with your corrective
2 action and decide if -- make sure everyone in the
3 industry knows about the problem, and if you need to do
4 more research in the area to initiate research
5 initiatives through a cooperative effort.

6 As we have reduced budgets, we all have to
7 work together. So, we try to now initiate cooperative
8 efforts if we find deficiencies.

9 MR. SWAIM: Thank you, Mr. Slenski. I think
10 that would go back to Mr. Dunn, because you are talking
11 about programs and industry and so forth. My -- how
12 would that tie in with you? Are you bringing that into
13 your program?

14 WITNESS DUNN: Well, can you be more specific
15 on what things you are talking about?

16 MR. SWAIM: As far as looking for wiring
17 problems, active hunts for wiring problems rather than
18 on condition type maintenance?

19 WITNESS DUNN: Yes, most certainly the plan
20 that I talked about earlier does intend to look into
21 issues of wiring, specifically. Also, George mentioned
22 tools, tools for finding out if we have defects in
23 wiring. That is also an issue we will be looking at as
24 we do our field inspections.

25 We are going to look at DC-9's, DC-10's, Air

1 Bus 300, DC-737's and we will be looking at those
2 issues specifically, yes.

3 MR. SWAIM: Okay. I would like to, since --

4 CHAIRMAN HALL: Who is the FAA wire expert?
5 Is that Mr. Crow, or do you have a wiring expert
6 equivalent to Mr. Slenski or Mr. Taylor?

7 WITNESS CROW: Mr. Chairman, I don't know in
8 particular anyone that is the wiring expert in the FAA
9 Flight Standards. That would probably fall back to the
10 Certification Service somewhere. So, I --

11 CHAIRMAN HALL: It is probably Mr. Donner.
12 Let's go ahead.

13 MR. SWAIM: Okay. My question for Dr. Dunn,
14 then, is, using as an example the 1991 recommendations
15 from the Safety Board following an L-1011 incident, an
16 in flight fire from wiring, we are recommending -- the
17 Board recommended, I am sorry -- that the FAA notify
18 all the operators of lint build-ups and foreign
19 materials in the wiring and clean the wiring, and I am
20 using that as an example.

21 How do we know that your programs that you
22 are talking about are going to take effect, because we
23 were examining airplanes that if they had been taken
24 out of service earlier this year would have been
25 examining operational airplanes and we are still seeing

1 lint and other debris in the wiring.

2 WITNESS DUNN: I guess when you say "how do
3 we know the programs are going to take effect," what --
4 can you be more precise?

5 MR. SWAIM: Well, you have spoken several
6 times about issuing a recommendation sometime around
7 June.

8 CHAIRMAN HALL: Well, he has discussed this
9 several times, Mr. Swaim. He is developing a program,
10 and I don't think you have the program right now,
11 right, Dr. Dunn?

12 WITNESS DUNN: No, sir, I don't.

13 CHAIRMAN HALL: And they will have the
14 program in June of next year.

15 MR. SWAIM: Okay, well, we will wait and see.

16 WITNESS DUNN: Mr. Chairman?

17 CHAIRMAN HALL: Yes.

18 WITNESS DUNN: At some time I think it would
19 be useful for the American public to get kind of a
20 better overview to the industry's approach to aging
21 systems as it exists now. We kind of talked about it a
22 little bit. We have talked with Mr. Craycraft, we
23 talked a little bit about Boeing, but I think it would
24 benefit the public and the record, certainly, if we
25 spent maybe -- and digressed about ten minutes.

1 I have some comments I would like to make,
2 and I think Mr. Crow would also like to, I think, step
3 back a little bit. We have talked about a lot of very
4 specific things of wire. At some point during this
5 panel discussion, whenever you think appropriate, I
6 would certainly like to --

7 CHAIRMAN HALL: Well, this would be fine
8 right now, Dr. Dunn. Please proceed.

9 WITNESS DUNN: Okay, fine. I think my -- I
10 do want to say that -- I have a few comments, and then
11 I would like to pass it over to Mr. Craycraft to
12 further comment on the maintenance aspects.

13 With that said, I think it is important to
14 talk a little bit about our current approach to aging
15 systems and how we address aging systems now, because I
16 feel it is a good story, I feel that we are doing in
17 general a good job, but I want to preface my following
18 remarks with saying that there is always room for
19 improvement, and we continually are looking at the
20 system.

21 CHAIRMAN HALL: Well, and let me just inject,
22 Dr. Dunn, so that, again, the American people know that
23 the Boeing 747 has an outstanding safety record, and I
24 think that is part of our public information and is
25 part of the docket that has been submitted.

1 Obviously, the whole aviation safety record
2 in the United States, if we would have the same safety
3 record on the highways we would probably save in excess
4 of 35,000 lives a year.

5 So, but what we are doing here and what the
6 Board is tasked is the responsibility of through this
7 accident investigation and working with the FAA and the
8 parties trying to explore every avenue, because we
9 don't know. If we knew, it might be a different
10 situation, but we don't know, so we are trying to look
11 and be sure that the American people know that we have
12 looked at each and every possibility so that if there
13 is --

14 We can do two things. One, hopefully find
15 the probable cause of the TWA 800 tragedy and,
16 secondly, advance aviation safety through the public
17 dollars that are being spent on this investigation,
18 which is certainly not a small sum of money. Please
19 proceed.

20 WITNESS DUNN: Thank you.

21 (Tape change.)

22 First of all, on the design side of the
23 house, the Aircraft Certification Office, there is a
24 lot of ways that they get involved in the continuing
25 process.

1 Maintenance and the operator handle the
2 aircraft once it has been approved in design. However,
3 the engineering gets involved still to a great extent.
4 We have all talked about Airworthiness Directives today
5 which are areas where -- where we find an unsafe
6 condition and then we correct it. That is certainly
7 one area that the Certification Engineers get involved.

8 In addition, there are daily reports which
9 come to the engineers and to the maintenance people in
10 the Certification Offices which are reviewed so that
11 people see on an ongoing basis what problems are out
12 there with the operators, the air traffic controllers,
13 what kinds of things they are saying.

14 So, this gives us additional opportunity to
15 look at the ongoing way the airplane is being operated
16 in service and the way it is being maintained and it is
17 operated to make sure it continues to be safe.

18 As well, when we go and we approve the
19 design, we have safety analysis. We have talked about
20 that a little bit previously. But, I do want to say
21 that when you talk about aging you are talking about
22 deteriorating effects. You are saying the wire
23 chaffed, the wire shorted and things like that.

24 Well, when we design the airplane we
25 postulate right up in the beginning that these things

1 are going to happen. So, when the safety analysis is
2 done, and we do this as part of the design and approval
3 process, we postulate these shorts, we postulate the
4 fact that these kinds of events will happen. Even
5 though we aren't thinking in terms of aging, it
6 actually is aging related.

7 So, those are some of the areas that we get
8 involved in, but after that, of course, there is a
9 whole maintenance program that is set up with the
10 operators that is done under Part 121 for large
11 transport aircraft. That is where Bill Crow I think
12 could perhaps give you some comments.

13 WITNESS CROW: I would be happy to share that
14 information with you, Mr. Chairman. I think it is
15 important because it does, as I indicated earlier,
16 close the loop, if you will, on continuous
17 airworthiness concerns and the programs and policies
18 and procedures that are in place.

19 I am not going to endeavor to quote any
20 Federal Aviation Regulations, or even paraphrase them,
21 but for the record I would like to give just a few --
22 four that are appropriate that all of the air carriers
23 use in the performance of their maintenance and such as
24 that.

25 Of course, going all the way back to Part 25,

1 this is a very important thing. It is the design
2 criteria for certification. But, in particular, one
3 that we are very interested in today is 25-571, the
4 damage tolerance and fatigue evaluation for transport
5 category aircraft.

6 As Dr. Dunn spoke earlier, the Appendix H of
7 that does require specifically that continued
8 airworthiness maintenance manuals and limitations be
9 provided to the operators of those aircraft for the
10 continuous maintenance of that particular airplane.

11 In addition to that, we have to go back into
12 the FAR and we look at 4313 A and B which are
13 performance rules that are mandated to all people at
14 all categories of airplanes for the safe and efficient
15 maintenance of those aircraft.

16 Then we go to 4315. 4315 is additional
17 performance requirements that are placed on the
18 industry for the maintenance of their aircraft. We go
19 to 4316 which basically has to do with operation
20 specifications, and the key element in that FAR is a
21 statement by the Administrator that says that the
22 agreements that are reached in the authorization
23 document, the operation specifications between the air
24 carrier and between the FAA are mandatory and must be
25 followed, and that takes us to the aircraft maintenance

1 manuals and the continuous airworthiness maintenance
2 program.

3 We also have 91-409, that in paragraph E and
4 F determines the types of requirements that are put on
5 the major carriers. In this particular case, all FAR
6 121 aircraft, and even those in the 135 category, as we
7 know, they are now falling under 121 rules for
8 continuous airworthiness maintenance programs.

9 We have a 119-43 which again talks about --
10 this is one of our new FAR's that talks about operation
11 specifications and reiterates the responsibility to
12 follow those.

13 121-367 is the first 120 regulation -- 121
14 regulation that we talk about, and it identifies the
15 maintenance programs that must be in place by
16 regulation for maintenance -- preventative maintenance
17 and alteration. Then we go to one very important
18 consideration within that 121 reg. It is 121-373,
19 continuous analysis and surveillance.

20 In all of these programs are the things that
21 our friends down there at the IAM table deal with on a
22 daily basis. These are the people that are responsible
23 for the continued airworthiness of the airplanes that
24 are flying out in industry.

25 These are the people that are working in

1 coordination with our engineer friends in the Aircraft
2 Certification Service and with the FAA, in particular
3 Flight Standards Service. The work that they do has an
4 immense impact on the way the aircraft perform the
5 longevity in service and airworthiness of those
6 airplanes.

7 So, I would suggest to the Board that the
8 continuous airworthiness requirements for aircraft
9 really come in about three phrases, two that you can
10 really lay your hands on in good fashion. One of them
11 is the certification responsibility. In particular,
12 25-571. Then, the regulations that I have given you
13 are those maintainability and performance regulations.

14 The importance of this thing from a Flight
15 Standards perspective is to understand that we are
16 immensely interested in the level of safety, the
17 inherent level of safety that is designed into the
18 airplanes and the level of safety that is placed in the
19 airplanes on a daily basis by the mechanics.

20 We can spend an eternity looking at
21 certification issues, and if we ignore the
22 maintainability side of the airplane, then we have done
23 half a job. That is a Bill Crow opinion, that is not
24 the Director of Flight Standards opinion, and I want to
25 go on the record as saying that.

1 It is very important to understand that
2 within those maintenance programs that our friends from
3 TWA and the major carriers and all of the carriers
4 certificated under Part 121 for that fact, the programs
5 that they have offered great evidence as to the systems
6 function, Dr. Loeb.

7 One of the things that you find when you look
8 at aircraft specifically as an entity, as an
9 electromechanical machine, is that there are certain
10 criteria, there are certain things in that airplane
11 that are critical zones, critical environments.

12 In listening to the testimony today, I
13 couldn't help but sit back there in the observer's area
14 and recall the many times that I have been in fuel
15 tanks and knowing what that critical environment is.

16 Another critical environment is the aircraft
17 wiring, and the point that I would like to make
18 regarding that, calling those critical environments
19 is -- I would like to give you an analogy, if I could.
20 The analogy would be one that runs to someone that is a
21 surgeon, if you will, and is going to perform surgery
22 on a gurney or an operating table in a hospital.

23 If a person was to go in for major surgery at
24 some time and he had a specific symptom, then that
25 surgeon would go in there and he would do -- he and his

1 team would go in and do the work that needed to be
2 done, and while they were in that general area, as we
3 refer to on air carrier maintenance, in particular MSG-
4 2 and 3 aircraft, the zonal concept of inspection, he
5 would look around in there and see what else he could
6 find, and we would do the same thing on the zone
7 concept of the inspections that we use for the aircraft
8 on the continuing maintenance requirements when an
9 airplane is in service.

10 But, I don't believe that a surgeon would go
11 in without symptomatic cause, or purpose, or intent and
12 perform surgery in an area that was critical to the
13 well-being of that patient.

14 For the same purposes, our mechanics that are
15 represented by the IAM and other people that are
16 maintaining these airplanes, we like to go into these
17 areas that are considered to be critical areas,
18 critical environments, on a need basis.

19 If we open those areas, if we open those fuel
20 tanks, if we get into systems maintenance where there
21 is no symptomatic indication of a problem, sometimes,
22 as was brought out in the expert testimony before, you
23 can cause more damage than you may have during the life
24 cycle of that particular airplane. So, it is very --
25 it is a very -- it is a very passionate discussion when

1 you get into trying to determine the right thing to do.

2 The Federal Aviation Administration, and I am
3 speaking on behalf of myself and, again, not for the
4 Director of Flight Service -- Flight Standard Service,
5 but it is very important that we stand firmly in our
6 position as given to us in the regulations.

7 We should not blow with the wind in one
8 direction, or blow with the wind in the other
9 direction. We should not take action until such time
10 we are absolutely sure of the probable cause, because
11 when you develop a periphery of perception, you may do
12 exactly the wrong thing.

13 I wanted to share these with you because I
14 think it is important when we look at this TWA 800
15 accident and the people that have lost loved ones and
16 all of the things that circle -- that come around this,
17 we in Flight Standards right now, we really have no
18 probable cause, as you have no probable cause.

19 We have ideas, but it is very difficult to
20 stand firmly in that position and not waiver until such
21 time we do have the findings we can really work with,
22 and I think it is important to note that when the
23 Flight Standards does have that information, they will
24 take swift and immediate action to make sure that that
25 is remedied.

1 I think that the maintainability is a very
2 important issue regarding this continue airworthiness
3 thing, and moving away from certification to make sure
4 that we recognize that.

5 One of the things that I recall listening to
6 this morning is the discussion about structures and
7 systems. I want to use some of my own vernaculars to
8 try to describe this, and my engineering friends here
9 may disagree with what I say, but I think they will
10 know where I am coming from.

11 When you start looking at aging aircraft and
12 you start looking at the symptomatic problems, that you
13 see there are a lot of latent failures that you don't
14 see. That is inherent in the way we look at some of
15 the airplanes. For instance, the structures, the
16 primary structures of an airplane probably fall
17 somewhere between passive and dynamic, where the
18 systems on the airplane are typically dynamic.

19 As George Slenski indicated earlier, most
20 symptoms that are identified in systems problems are
21 systems that have rotating parts that are driven by
22 electromotive force. They have some sort of a
23 mechanical function, where the structures don't. As I
24 indicated, they are from passive to dynamic, so we
25 don't see those.

1 But, when you have a failure in a system,
2 even with associated wiring you generally have some
3 sort of a symptom. You generally have something like
4 that. So, the air carrier industry has the reliability
5 programs where they take the pilot reports -- and we
6 refer to them as pi-reps. Our friends at the Air Line
7 Pilot's Association know well what those are. They
8 drive the air carrier reliability programs.

9 They set alert levels for the maintainers,
10 such as Mr. Craycraft and others in the engineering
11 functions to look at to see how those systems are
12 performing. It is not as if as we speak there is not
13 programs in place that are not necessarily required by
14 the FAR, but that are encouraged by the FAA to identify
15 systemic problems that will show degradation of the
16 systems.

17 In addition to that, the one FAR that I
18 suggested to you, the FAR 121-373, is the continued
19 analysis of surveillance requirement, and it is
20 mandatory. This is a continuing certification
21 requirement for an air carrier certificated under Part
22 121.

23 To fail to meet that requirement would place
24 a certificate holder's certificate in jeopardy. This
25 is the item that causes the certificate holder to

1 determine through careful analysis the performance of
2 their maintenance, preventative maintenance and
3 alteration.

4 It also causes them to look and analyze all
5 of the activities surrounding the maintenance
6 organization. The basic difference between a CAS
7 program that is mandated by the FAR and the reliability
8 program, as far as being able to make determinations on
9 the reliability of the aircraft or the systems, is
10 based in one thing; with the reliability program the
11 operator has the authority without prior approval to
12 adjust maintenance and inspection intervals, where with
13 the CAS program they still come to the FAA before they
14 make those changes.

15 So, there are a lot of devices, there are a
16 lot of processes and a lot of programs in place that
17 support continued airworthiness of these airplanes that
18 are designed by our engineers and built by our
19 manufacturers, purchased by our air carriers, flown by
20 our pilots and maintained by the maintainers.

21 So, I want the general public to know that
22 once an airplane leaves the drawing board and once an
23 airplane leaves the manufacturer, once that airplane is
24 in service that airplane is maintained on a daily basis
25 in strict accordance to the regulations.

1 But, for the most part -- and that is
2 probably a bad choice of words, but I don't know what
3 other vernacular to use, they are being maintained at a
4 very high state of airworthiness.

5 The anomalous situations that do occur with
6 the tragic catastrophic problem that occurred with TWA
7 800 and other aircraft probably are a small place on an
8 array of data. But, nevertheless, there are no
9 unacceptable losses. We can't have -- there are no
10 acceptable losses.

11 But, the continued airworthiness maintenance
12 program that is provided under the regulations and
13 overseen by Flight Standards Service in conjunction
14 with and coordination with where problems arise and
15 things are identified that need to be fixed with the
16 Certification Service, they are being looked at on a
17 continuous basis.

18 We spend a great deal of time with our
19 certificate holders and we are very cognizant of the
20 need for change, and we would just like to make sure
21 that the Board is very aware of its continuous
22 airworthiness requirements, aside from the
23 certification issues.

24 CHAIRMAN HALL: Well, thank you, Mr. Crow,
25 for that presentation. One clarification I want to be

1 sure of, though, so there is no misunderstanding, I
2 think, with the general public. If the FAA and the
3 NTSB find problems with any particular aviation
4 accident investigation, I don't think you were saying
5 that the FAA is going to wait until there is a probable
6 cause to act on those problems?

7 WITNESS CROW: No, sir, you are exactly
8 right. We would not wait and we would cooperate very
9 professionally and effectively with all of the other
10 entities that were working. But, one of the most
11 difficult things to do in this world is to identify a
12 corrective action for a discovery that has yet to be
13 discovered.

14 So, we want to go on record and we want to
15 continue to say that we are very interested in knowing
16 anything and everything about the accident where we may
17 take appropriate action.

18 CHAIRMAN HALL: Okay, other comments? Do you
19 want to continue on?

20 (No response.)

21 What I am going to suggest doing is
22 continuing until 12:30, and take a one hour lunch break
23 to 1:30. Again, I know the only people that are
24 interested in this going to day five are probably the
25 taxpayers of Baltimore, but nevertheless we need to

1 finish our work here and I would -- the prudent --

2 Everyone is asking me for advice, and the
3 prudent thing I would suggest is be prepared to be here
4 tomorrow. If we can finish today, fine, but if in
5 terms of -- I know people have hotel rooms and flight
6 reservations, and I would say that the prudent thing to
7 do is to plan for departure tomorrow.

8 We have not gotten into the AD Service
9 Bulletins on TWA 800, which is something I would like
10 to do before we get to do the parties. But, possibly,
11 Mr. Swaim, unless you have something else you want to
12 get into, we will just take a little longer than usual
13 lunch break, and we will reconvene here promptly at
14 1:30. Off the record.

15 (whereupon, at 12:15 p.m. a luncheon recess
16 was taken.)

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1 required of them.

2 While these four days of proceedings have
3 been highly technical affairs, I again would like to
4 state that I think that they are essential in seeking
5 to reinsure the public that everything is being done
6 that can be done to insure the safety of the airline
7 industry and find the probable cause of the TWA 800
8 tragedy.

9 Mr. Swaim, please proceed.

10 MR. SWAIM: Thank you, sir. I only have a
11 couple more, and we will be into Debbie Eckrote and
12 Maintenance Records, the maintenance of the airplane.

13 (Slide shown.)

14 The photo -- there are two photos there, one
15 in the upper left corner and one, the larger photo.
16 The smaller inset is of a wiring fire, and the other is
17 of lint on wires we found behind a flight engineer's
18 panel of another 747.

19 My question is to Mr. Taylor, Alex Taylor.
20 In your reviewing wiring problems and aging wiring
21 problems, does it taken into consideration problems
22 that can happen in a general area like this, or is it
23 more to an individual wire?

24 WITNESS TAYLOR: I don't really understand
25 the question. Could you re-word it a little bit,

1 please?

2 MR. SWAIM: In the consideration of aging
3 systems, and you spoke very well about wiring, was that
4 mostly pertaining to individual wires, or bundles of
5 wires? That is where I came with this question from.

6 You spoke of bundles of wires, but in this
7 photo we have a number of wires -- bundles shown
8 together. Would that type of review be on a detailed
9 engineering paper level where it would consider just a
10 bundle, or would it consider an area such as seen here
11 with a number of bundles?

12 WITNESS TAYLOR: When I refer to wiring on an
13 airplane, I refer to all the wires on the airplane in
14 whichever particular configuration that may be at
15 whatever location on the airplane. Wiring is wiring,
16 whether it is a single wire, or a bundle, or a bundle
17 of bundles.

18 MR. SWAIM: So, for the failure
19 considerations from aging, would it include a failure
20 of a bundle -- I am not making this clear, I guess.
21 Would it include -- is there some type of detailed or
22 systemic analysis to include all the bundles within an
23 area as you see here?

24 WITNESS TAYLOR: In the analysis that is
25 undertaken, the design of the bundle is such that we

1 can lose a wire within that bundle and it will not
2 affect the safety of the airplane, or we can lose a few
3 wires within that bundle and it does not affect the
4 safety of the airplane. We can lose that whole bundle
5 and it will not affect the safety of the airplane.

6 MR. SWAIM: Lose that whole area with the
7 lint build-up on it?

8 WITNESS TAYLOR: That is an area, that is not
9 a bundle. That particular photograph you have there is
10 more than one bundle. It is an area, but within that
11 area there are numerous bundles, and many of them are
12 separated from that picture by a foot or more, and that
13 is more than adequate separation to make sure there
14 would be no propagation of any failure of one of these
15 wire bundles to another.

16 MR. SWAIM: Okay. I would like to move out
17 of wiring, we have been discussing wiring very
18 extensively, and ask a couple of questions of Mr.
19 Thomas about leakage.

20 When we discuss leakage, this is a photo we
21 have seen before of the corner of a corner in the
22 center tank, and there are three colors that can be
23 seen of sealant, and when we discuss fuel leaks -- and
24 we are showing different layers of sealant here -- when
25 we discuss fuel leaks in aging aircraft, how is that

1 considered, Mr. Thomas?

2 WITNESS THOMAS: Fuel leaks are considered
3 right from the start of the design of the airplane. We
4 recognize that at some point the wings are flexing.
5 Most all our fuel tanks are generally located in the
6 wing. The wing flexes up and down. Occasionally we
7 will develop leaks.

8 That is taken into consideration right from
9 the beginning of the design of the airplane. We assume
10 that we are going to have fuel leaks. We typically
11 will -- typically all the time we will divide the
12 airplane into zones. The leading and trailing engines,
13 for example, are considered fuel leak areas where a
14 single failure can cause fuel to leak into those areas.

15 We require all the electrical components in
16 the leading and trailing edge to be explosion proof.
17 We require that temperatures of ducts to be below 450
18 degrees fahrenheit, again, for hot surface ignition
19 issues.

20 We provide very careful drainage and dams in
21 the leading and trailing edges to assume that any leak
22 is directed to a drain hole and overboard safely. For
23 instance, if you have a leak outboard of a strut, we
24 will have a dam outboard of the strut to stop the fuel
25 from running down onto themselves where it may catch

1 fire in the engine area.

2 The same thing at the side of body. There is
3 a seal rivet the side of body. So, again, if I have a
4 leak inboard of the engine, it will just run to the
5 side of body and go overboard through a drain line and
6 not propagate anywhere that it could be hazardous.

7 Does that answer your question?

8 MR. SWAIM: Would the area under the tank,
9 below the center tank in this case, be considered an
10 area that you have to run the same electrical
11 protections as you would in the fuel tank for ignition?

12 If you have a leak out of the fuel tank into
13 that area below the fuel tank, and you have wiring down
14 there, what consideration is given for the fuel --
15 which one is the latent failure, or trying to prevent a
16 latent failure, that you could have the fuel, say, leak
17 onto a bundle of wiring, or if you have wiring that
18 ignites a fuel leak down in that area?

19 WITNESS THOMAS: Out there you are dealing
20 with the first failure which is a leak, which is
21 readily available -- readily observable to the crew or
22 to mechanics doing a walk around the airplane. You
23 will see the fuel dripping out of the -- in this
24 particular example you have chosen, the pack bay area.

25 The pack bay is designed to be -- all the

1 temperatures in the pack bay are below 450. By design
2 the hot air that comes from the engines are controlled
3 to below 450, as I have discussed several times in the
4 last few days.

5 The packs themselves, although we talk about
6 them being hot, are all running in the -- at the
7 maximum, something in the 350 range, and a lot of the
8 packs are much cooler than that.

9 None of those are ignition sources. The
10 electrical bundles, as far as I know -- and I would
11 defer to Mr. Taylor on the details of connectors -- are
12 not a source of ignition while that leak is taking
13 place.

14 The assumption that we would make is that the
15 leak is very detectable and the airlines can fix the
16 leak. We have very carefully defined -- and I can't
17 quote them off the top of my head, but we have very
18 careful ways of defining a fuel leak, whether it is a
19 weep, or a seep, or whether it is a drip and what
20 procedures go along with repairing the airplane when
21 those things take place.

22 MR. SWAIM: Okay. I think at this point I
23 would like to turn it over to Ms. Debra Eckrote. She
24 is our Maintenance Group Chairman for this accident.

25 MS. ECKROTE: Thank you, Bob. I just have a

1 couple questions. The first one I would like to ask of
2 Dr. Dunn. Earlier we had been talking about the
3 corrosion control program and the structural inspection
4 programs.

5 Would you please discuss the AD's and Service
6 Bulletins that have been generated as a result of these
7 programs, and also would you also discuss if there are
8 any future AD's or Service Bulletins that are being
9 proposed?

10 For reference for the audience, the list of
11 all the applicable AD's on the aircraft at the time of
12 the accident can be found in Exhibit 11-P. Mr. Dunn --
13 or, Dr. Dunn?

14 WITNESS DUNN: I can't address corrosion
15 AD's. That is not an area of my expertise. However, I
16 do have some overheads that we can show that talk about
17 AD's that we have put together since we have known
18 about this accident.

19 MS. ECKROTE: Thank you.

20 WITNESS DUNN: This is the first one we will
21 talk about.

22 (Slide shown.)

23 Incidentally, I want to make clear that I am
24 presenting these slides on behalf of Chris Hartonis
25 (sic) of the Seattle Aircraft Certification Office who

1 did prepare these for me.

2 This first AD that I am going to talk about
3 here is actually an NPRM. It says "Air Worthiness
4 Directive," but it is actually at this point an NPRM
5 that is out for comment.

6 It was published in the Federal Register I
7 believe the first of this month with a ninety day
8 comment period and a one year compliance. This
9 involves 747 fuel quantity system wiring. That is an
10 AD that relates to the wiring on board the aircraft in
11 order to prevent ignition sources from entering the
12 fuel tank.

13 Next slide, please.

14 (Next slide shown.)

15 What this AD proposes to do is to install
16 transient suppression and/or shielding and separation
17 to the wiring of the FQIS system.

18 Next slide.

19 (Next slide shown.)

20 I guess it is appropriate at this point to
21 discuss what shielding is and why it is important. As
22 it says up there, shielding is electromagnetic.
23 Electromagnetic shielding is a technique that reduces
24 or prevents coupling of undesired radiated
25 electromagnetic energy in equipment.

1 The concern here is obviously coupling energy
2 from one wire into another wire such that you would
3 ultimately get a certain amount of energy, if you will,
4 into a wire which might subsequently -- that energy
5 might find its way into the fuel tank.

6 Next.

7 (Next slide shown.)

8 A transient suppression device is a device
9 used to limit the amount of energy. It is a surge
10 protector, so that if you get this coupling from one
11 wire into another, this energy coupling from one source
12 into another, you want to make sure that if indeed it
13 does happen you can make sure that that energy is not
14 propagated ultimately into the tank.

15 So, what you do is you insist that you stop
16 that from happening, or essentially cause that energy
17 to be shorted to ground prior to entering the fuel
18 tank. Shielding is one way of doing this. Using a
19 transient suppression device is another way.

20 Next.

21 (Next slide shown.)

22 So now what we have got here -- as this AD
23 relates to this accident, what we have got here is we
24 want to make sure that we don't get any kind of energy
25 into the fuel tank from whatever source, and we -- and,

1 so, what we have done is we have gotten very -- shown
2 here is a bunch of sources here of possible energy
3 sources that might get into the tank.

4 On the left you have voltage sources, induced
5 transient, one wire, like someone shuts off a switch or
6 something and that wire -- the energy in that wire is a
7 result of the -- of -- that transient is produced and
8 couples into another wire. So, that is the first one
9 there.

10 Then, of course, the hot short where you have
11 a chaffing of that where the energy from one wire
12 physically touches another wire and subsequently
13 might -- that energy might get into the fuel tank.

14 On the right are sources within the tank of
15 possible -- possible debris and possible conducting
16 sources. You have copper sulphite, as we talked
17 earlier, and you have debris, maybe wire shavings and
18 things like that, damaged wire insulation and damaged
19 probes. All of those are sources we need to protect
20 against.

21 Next.

22 (Next slide shown.)

23 What this slide attempts to do is to show you
24 kind of what really happens when you get induction, and
25 it is for illustrative purposes only. At the top you

1 have a motor in one system and then -- represented as a
2 wire between an indicator and a motor, and then at the
3 bottom you have yet another system. As a result of a
4 common bundle they come in contact with each other.

5 So, what you are trying to do with this AD is
6 to put in place methods whereby you can't -- you
7 suppress any coupling from one wire into the other, and
8 the three techniques that we have talked about were in
9 separation where we can make those wires -- we can
10 separate those wires.

11 We can shield one of those wires so that it
12 can't -- the energy cannot couple into the other, and
13 then we can -- also, a third technique would be to use
14 a suppression device prior to the fuel tank to insure
15 no energy enters the fuel tank.

16 Is there another slide, or is that it?

17 (No response.)

18 Is that it? Okay. So, that is the current
19 NPRM that we have out now that we are trying to
20 address. Now, there was also a question that related
21 to other AD's, is that it?

22 MS. ECKROTE: Do you have any knowledge of
23 the AD's that are presently open regarding the
24 structural inspection, or the Corrosion Control
25 Program? Can you discuss that? Or, I can direct that

1 maybe to Mr. Craycraft and see if he can kind of
2 discuss some of that during his maintenance review?

3 WITNESS DUNN: Yes, I -- I am not really --

4 MS. ECKROTE: Okay.

5 WITNESS DUNN: I can't really address that.
6 I did want to -- I should reiterate that that is an
7 NPRM that is out now for comment.

8 WITNESS VANNOY: Debra, this is Bob Vannoy.
9 I can summarize those AD's for you, if you would like.

10 MS. ECKROTE: Thank you, please.

11 WITNESS VANNOY: Okay, out of the activities
12 that were generated after 1988 with the Structures Task
13 Groups there were three main areas that were covered by
14 AD's.

15 Number one was the Mandatory Service Bulletin
16 Modification and Inspection Program. The second was
17 the Corrosion Prevention and Control Program. The
18 third one was the SSID Program which previously had an
19 AD, but new work was done.

20 In all three cases, the working groups, the
21 airlines, Boeing and FAA, as observers and advisers,
22 prepared documentation. Boeing put out the documents,
23 and then the AD's that followed were fairly simple and
24 just said go do what is in the document.

25 So, for the Mandatory Bulletin Inspection and

1 Modification Program the AD was fairly simple. It was
2 90-06-06. Early in 1990 it just said go do what is in
3 the Boeing document, which was a D-6 document produced
4 by Boeing and contained a list of all the bulletins
5 covered, and then the airline took that and had to pull
6 out all the bulletins and then go put all that in their
7 Inspection and Maintenance Program.

8 MS. ECKROTE: Are these AD's a one time
9 event, or are these repetitive?

10 WITNESS VANNOY: Well, for the Mandatory
11 Modification Program, that is a one time event. When
12 the airplane reaches the prescribed threshold you do
13 the parts replacement, or whatever is called for.

14 The Corrosion Prevention and Control is
15 ongoing. You have to establish a program for every
16 airplane and do that work essentially forever. The
17 SSID applies, as I said this morning, to the sample
18 fleet, and that is ongoing as long as those airplanes
19 remain in service.

20 MS. ECKROTE: Thank you. I think it would be
21 a good time right now if we can ask Mr. Craycraft -- we
22 have been hearing a lot of testimony about all these
23 programs, but we haven't really heard how TWA
24 incorporates it into their program.

25 Mr. Craycraft, could you spend a little bit

1 of time. I know this is a broad area and you could
2 spend all day on it, but if you could just highlight
3 your -- a break-down of your scheduled maintenance, and
4 I know the Chairman had a question yesterday about the
5 frequency of scheduled maintenance, and I don't think
6 we really got a good answer on it.

7 Would you please also discuss the frequency
8 that TWA inspects their program -- or, inspects their
9 aircraft?

10 WITNESS CRAYCRAFT: Okay. If I might, I
11 would start at the most frequently accomplished task,
12 which is a periodic service. That is the
13 identification that we put on it. That is accomplished
14 at a maximum interval of every other operating day when
15 we accomplish a periodic service.

16 The next level of maintenance is
17 accomplished. We call it an aircraft service, or an
18 AS. That is accomplished at intervals not to exceed
19 100 hours of aircraft time in service.

20 These are accomplished at numerical
21 increments. There may be an AS-1 and an AS-2, an AS-3
22 and so forth until it gets up to the next level of
23 maintenance which is a time control service. The time
24 control service is accomplished each 1,200 hours of
25 service and, of course, a TCS includes all of the items

1 that are required on an aircraft service.

2 Then the next level of operation would be a
3 Check-C. A Check-C is accomplished at intervals not to
4 exceed thirteen months. We have gone at different
5 times with an hour interval on our Check-C, but we have
6 since changed to a monthly control to kind of fit in
7 with the Corrosion Control Program. So, that is why we
8 went to a monthly figure on the Check-C.

9 I think we referred to the Check-D, and I am
10 looking here. I thought it was an Op-16. No, here we
11 go. Op-16 is what is commonly referred to as a D-Check
12 under some or other aspects.

13 An Op-16 is a number of unit changes that we
14 schedule, structural checks and inspections. That is
15 the time that we get into the center wing tank for
16 structural inspection and so forth. That is scheduled
17 not to exceed forty-eight months for accomplishing an
18 Op-16.

19 MS. ECKROTE: Is the D-Check the heaviest
20 maintenance activity?

21 WITNESS CRAYCRAFT: Well, we do have another
22 check that is accomplished at every other D-Check that
23 is called an Op-1, and it gets into further structural
24 items also.

25 But, it also -- anytime we do any Op-16,

1 which is every forty-eight months, then all of the
2 lower checks are accomplished during that time, and
3 then when we -- if we were not doing an Op-16, then we
4 would do the Op-1 and it would include everything that
5 is in the Op-16.

6 MS. ECKROTE: Thank you. At the Op-16, the
7 D-Check, is it at this point that, say, like the floor
8 boards are pulled up exposing wiring systems for
9 inspections?

10 WITNESS CRAYCRAFT: Well, it does get opened
11 up quite considerably, but the primary open-up activity
12 is for gaining access to all of the areas for
13 structural inspections.

14 While we are in there for the structural
15 inspections, our dear friends our inspectors, they have
16 what is called an area inspection and they are
17 responsible for inspecting all of the items that is in
18 an area, and if --

19 I will use the center wing tank as an
20 example. They are obliged to look at the fuel quantity
21 equipment, the wiring, the plumbing and everything else
22 that is in the center wing tank.

23 MS. ECKROTE: Are these area inspections
24 pretty common throughout the aircraft, not just the
25 center tank?

1 WITNESS CRAYCRAFT: That is correct. I just
2 used that as an example.

3 MS. ECKROTE: Thank you. I think those are
4 all the questions I have for this area. Unless someone
5 has any questions, we can get into the minimum
6 equipment list items.

7 CHAIRMAN HALL: Yes, I had a question I was
8 going to ask Mr. Craycraft. I believe on the accident
9 aircraft there were twenty-six fuel pump write-ups from
10 July 1, '94 to July 17, '96. Is that an unusual
11 number, or is that a standard number?

12 WITNESS CRAYCRAFT: I sounds a little
13 unusual. I have not reviewed the fuel pump. I was
14 looking at other items on the aircraft, sir.

15 CHAIRMAN HALL: Mr. Vannoy or Mr. Thomas, are
16 you all familiar with the Service Bulletin 74728-A-2194
17 that was issued August 3rd, 1995, revised January 18th,
18 '96?

19 WITNESS THOMAS: Is that the boost pump?

20 CHAIRMAN HALL: Yes.

21 WITNESS THOMAS: Could you give me the title
22 of that if you have it in front of you, sir?

23 CHAIRMAN HALL: Yes, it is the Fuel
24 Distribution Fuel Boost and Override Jettison Pumps
25 Inspection.

1 MR. THOMAS: Oh, this is --

2 CHAIRMAN HALL: In the background it starts
3 off, "This inspection will make sure the 747 fuel pumps
4 will not cause a leak, a fuel leak," and it says here,
5 "Boeing recommends that the initial inspection be
6 accomplished at the next opportunity."

7 I believe this is the only Service Bulletin
8 that was not -- that had not been accomplished on TWA
9 800, the accident aircraft. If I am incorrect in that,
10 Mr. Craycraft or someone at the TWA table I am sure
11 could correct me. but I would like to know exactly
12 what -- a little background on that Service Bulletin
13 and what --

14 WITNESS CRAYCRAFT: If I might, sir?

15 CHAIRMAN HALL: Yes, sir.

16 WITNESS CRAYCRAFT: That Service Bulletin was
17 being in the process of being evaluated and paperwork
18 prepared to be accomplished on TWA aircraft, but at the
19 time of the accident, then it became an AD and, so, it
20 was accomplished shortly thereafter.

21 CHAIRMAN HALL: Okay. Could we have a little
22 explanation from either Mr. Thomas or Mr. Vannoy as to
23 what that Service Bulletin was all about, or is -- I
24 don't mean -- if you are not -- maybe there is going to
25 be somebody else who could discuss that.

1 WITNESS THOMAS: My problem right now is
2 there was -- is this the conduit AD, or is this the
3 boost pump?

4 CHAIRMAN HALL: It says, "Since operators
5 have sent reports of fuel leaks at the fuel boost and
6 override jettison pumps, reports tell that eight fuel
7 pumps have been removed for this reason. The removed
8 fuel pumps had between 34,000 and 67,000 hours," et
9 cetera, et cetera.

10 WITNESS VANNOY: I think that is the
11 connect --

12 CHAIRMAN HALL: It says that there should be
13 an initial inspection at the next opportunity when
14 manpower facilities are available, and then it gives
15 some parameters on replacing the pumps.

16 WITNESS VANNOY: Yes, I can provide some
17 background and current status on that bulletin. The
18 bulletin was out before the accident, and you have a
19 copy there.

20 The concern originated when we had a leak on
21 an airplane that was in maintenance, and at the same
22 time there was an electrical short in the connector and
23 there was a small fire started in maintenance outside
24 the fuel tank.

25 After that we initiated an Alert Service

1 Bulletin to do some checks on the connector for the
2 possibility of leaking, and also an electrical check to
3 check for the wiring condition.

4 After the accident, that bulletin was made an
5 Airworthiness Directive, but the alert status of the
6 bulletin was pre-existing and the FAA was in the
7 process of doing that work before the accident, so it
8 had nothing really to do with the accident.

9 CHAIRMAN HALL: Well, I am not saying that it
10 did have anything to do with the accident. I just
11 noticed that that was the only Service Bulletin that I
12 noticed in reviewing the maintenance records, if I am
13 correct, Ms. Eckrote, that Boeing had issued that was
14 not -- the work had not been done on the airplane, and
15 it had been put out initially on August 3rd of 1995.
16 It said Boeing recommends that the initial inspection
17 be accomplished at the next opportunity when manpower
18 and facilities were available.

19 So, I will ask Mr. Vannoy and Mr. Craycraft,
20 is it a policy of most 121 operators that you all deal
21 with, or -- and what is the policy of TWA when Boeing
22 puts out a Service Bulletin? Do you wait for an
23 Airworthiness Directive, or do you -- what is your
24 experience with your operators in terms of that area?
25 It may just be on an individual basis, I don't know.

1 WITNESS VANNOY: Well, when we put out an
2 alert bulletin, we normally give the operators our
3 recommendations in writing as to the urgency. We also
4 usually tell them what we believe the FAA's intentions
5 are.

6 I think in this case at the time of the
7 accident most operators in the world had at least
8 inspected some of their airplanes, and most everybody
9 was complying with the recommendations of that
10 bulletin. So, TWA wasn't totally unusual. They had
11 not inspected all their fleet, and that was consistent
12 with other operators.

13 So, when the Airworthiness Directive
14 followed, of course it was mandatory, and not all
15 airplanes had been inspected per that requirement.

16 MR. SWAIM: Mr. Vannoy, what is an Alert
17 Service Bulletin versus a Service Bulletin?

18 WITNESS VANNOY: Okay, we publish an Alert
19 Service Bulletin. It is a higher priority bulletin
20 that is published on colored paper, where the regular
21 bulletins are on white paper, and it is a higher
22 priority, more urgent and normally signifies it has
23 safety implications.

24 CHAIRMAN HALL: Was this an Alert one, or
25 not?

1 WITNESS VANNOY: Yes, it was.

2 CHAIRMAN HALL: I got it on white paper. So,
3 it was an alert?

4 WITNESS VANNOY: Yes.

5 CHAIRMAN HALL: So, Mr. Craycraft, do you
6 know whether the TWA accident aircraft was inspected at
7 the next opportunity in regard to this Service Bulletin
8 74728-A-2194?

9 WITNESS CRAYCRAFT: I do not know that we
10 actually had the paperwork out yet to accomplish the
11 bulletin. I don't have those facts here in front of
12 me, sir. I can look and find out, but --

13 CHAIRMAN HALL: Okay, if you could provide
14 that for the record, I would appreciate it.

15 WITNESS CRAYCRAFT: Yes, sir. We have
16 adopted a policy within TWA that any Alert Service
17 Bulletin coming from Boeing we considered the same as
18 if it were a directive from the government.

19 CHAIRMAN HALL: Was that before or after the
20 accident?

21 WITNESS CRAYCRAFT: That was before.

22 CHAIRMAN HALL: Before the accident?

23 WITNESS CRAYCRAFT: Yes.

24 CHAIRMAN HALL: So, this should have been
25 treated as an AD?

1 WITNESS CRAYCRAFT: Yes, sir.

2 CHAIRMAN HALL: And the work should have been
3 done?

4 WITNESS CRAYCRAFT: Well, I can't answer the
5 timing.

6 CHAIRMAN HALL: Yeah. Did you find any
7 evidence, Ms. Eckrote, that this inspection had taken
8 place?

9 MS. ECKROTE: No, the inspection had not
10 taken place. However, during my maintenance review TWA
11 was in the process of completing a modification order
12 in preparation for the Airworthiness Directive that was
13 still being reviewed.

14 So, they weren't just completely ignoring the
15 Service Bulletin. They were going through the --

16 CHAIRMAN HALL: Well, I am not saying they
17 were ignoring it. I am just trying to understand.

18 MS. ECKROTE: Right, they were still in the
19 process of getting it into their system and it had not
20 been completed yet at the time of the accident.

21 CHAIRMAN HALL: But, now, your -- the
22 Maintenance Group's inspection, were there any other
23 AD's or Service Bulletins that had not been -- where
24 the work had not been performed on the accident
25 aircraft other than this one?

1 MS. ECKROTE: A review of the records
2 determined that all of the Airworthiness Directives
3 that were applicable at the time of the accident had
4 been accomplished.

5 CHAIRMAN HALL: With the exception of this
6 one?

7 MS. ECKROTE: This --

8 CHAIRMAN HALL: Well, this was not an AD.

9 MS. ECKROTE: Right, this was a --

10 CHAIRMAN HALL: What about Service Bulletins?

11 MS. ECKROTE: Again, Service Bulletins aren't
12 mandatory. We found some areas such as this one where
13 the Service Bulletin had not been accomplished. In
14 other areas the Service Bulletins had been
15 accomplished.

16 CHAIRMAN HALL: Do you have in the record the
17 Service Bulletins that had and had not?

18 MS. ECKROTE: No, I do have in my factual
19 report a reference to the Service Bulletin that we are
20 talking about right now and the fuel pump, and then the
21 Airworthiness Directives are referenced.

22 CHAIRMAN HALL: Well, I think it would be
23 appropriate for you to find out what the status was of
24 the accident aircraft on all the Service Bulletins that
25 were issued by Boeing because Mr. Craycraft said that

1 they had -- they are equivalent to AD's as far as TWA
2 was concerned.

3 MS. ECKROTE: I will look into that, yes,
4 sir.

5 WITNESS CRAYCRAFT: Let me rephrase that, Mr.
6 Chairman. That is Alert Service Bulletins, not all
7 Service Bulletins.

8 CHAIRMAN HALL: Just the Alerts?

9 WITNESS CRAYCRAFT: Yes, sir.

10 CHAIRMAN HALL: Okay, well then let's be sure
11 you clarify the difference between -- I apologize, Mr.
12 Craycraft. I was given so many pounds of paper to read
13 for this hearing, and I don't -- this is all on white
14 paper, and I appreciate knowing the difference between
15 the Alert and the regular Service Bulletin.

16 WITNESS CRAYCRAFT: I might help you a little
17 bit on that. An Alert Service Bulletin has an "A" in
18 the numbering system, such as the Service Bulletin you
19 are referring to is 74728-A-2092. The "A" indicates
20 that it is an Alert Service Bulletin.

21 CHAIRMAN HALL: Okay, other questions from
22 the Technical Panel?

23 (No response.)

24 MS. ECKROTE: I don't think so. I think we
25 are ready to get into the minimum equipment list

1 issues.

2 CHAIRMAN HALL: Well, I want to get into
3 this -- is anybody going to get into this one thing on
4 the -- there is one other thing that was stuck in my
5 memory, and that is on this shield, the work you did,
6 Mr. Thomas, on the shield, the Service Bulletin that
7 went out on the shield over the High-Z and Low-Z
8 fire -- wiring for the fuel quantity system.

9 Can either one of you all help me on what --
10 what that was issued for and what -- if that has any
11 significance?

12 MR. RODRIGUES: Mr. Chairman, Boeing -- the
13 Boeing table?

14 CHAIRMAN HALL: Yes.

15 MR. RODRIGUES: I have heard that is the
16 shield from the Madrid accident.

17 (Discussion off the record.)

18 WITNESS CRAYCRAFT: I think you are referring
19 to the Service Bulletin that was issued after the
20 Iranian accident; is that correct, sir? If it is, yes,
21 that was an AD, and that was accomplished on that
22 aircraft.

23 CHAIRMAN HALL: Well, I am referring to a
24 letter from October 2nd from Boeing to Mr. Swain, and I
25 will send it down and then -- while we continue. It

1 says "FQIS wire shielding, TWA 747-100 accident near
2 Long Island," and I don't see the exact date.

3 That may be it, but it came from Mr. Pervis,
4 and I just wanted to -- it was a -- what got my
5 attention was it was an action that was taken after the
6 initial design. My question was, why was the shield --
7 why was the shield added, or would you rather just have
8 the -- let me send this over, and then you can answer
9 that later, then.

10 WITNESS CRAYCRAFT: Mr. Chairman, if I could
11 ask a question for just a moment in your reference to
12 the fuel pumps?

13 CHAIRMAN HALL: Um-hum.

14 WITNESS CRAYCRAFT: Is that from the
15 maintenance records of the sixteen items?

16 CHAIRMAN HALL: Yes.

17 WITNESS CRAYCRAFT: I believe that identifies
18 the sixteen pumps that is in the aircraft and, so,
19 there is an entry there for every pump in the airplane
20 and its history on the airplane.

21 CHAIRMAN HALL: That's right.

22 WITNESS CRAYCRAFT: Not necessarily the
23 removal time. It just goes back the full back history
24 of when those pumps were installed and why.

25 CHAIRMAN HALL: Well --

1 WITNESS CRAYCRAFT: Some of them were for
2 routine --

3 CHAIRMAN HALL: Let me say, Mr. Craycraft, I
4 have -- there is nothing that has been presented to the
5 Board through the maintenance study that indicates any
6 concerns that I am aware of at this time in regard to
7 the maintenance of the aircraft.

8 However, there are some things that I was
9 trying to understand so that we could be sure that we
10 cover all of this, and in reading all this material I
11 noted, because we had a great deal of discussion about
12 the probes and the wires, and of course the probes had
13 wires and the wires run through various parts of the
14 airplane, and we also have in the tank pumps -- and
15 that was --

16 The purpose of my question was -- looking at
17 the write-ups on the pumps -- was whether that was
18 anything -- anything unusual, or not. Was -- and that
19 just kind of stuck at me, plus the fact that the --
20 that this was the only Service Bulletin that Boeing
21 had -- I guess it was an Alert Service Bulletin that
22 the Chairman is aware of that had not been performed,
23 and I thought there should be some explanation on the
24 record for what that was.

25 Again, we have no way of knowing whether that

1 had anything to do or not with the TWA 800 tragedy. We
2 are just trying to be sure that we cover each -- you
3 know, each trail that we should.

4 WITNESS CRAYCRAFT: Yes, sir, and a quick
5 review of those sixteen items, there are -- it has
6 identified every pump on the airplane and the date it
7 was installed, and at quick glance -- here is one, for
8 example, that had been installed in 1991.

9 So, that goes back to a clear installation
10 record of all of the pumps. So, that is why there is
11 sixteen entries; there is one for every pump, sir.

12 CHAIRMAN HALL: No, I am talking about write-
13 ups, not entries. But, you are telling me that when
14 the pump is installed that is a write-up, as well?

15 WITNESS CRAYCRAFT: Yes, sir, that is an
16 identification.

17 CHAIRMAN HALL: Okay, that's very helpful,
18 because I don't want to have any mis-impressions on
19 that at all. Well, you proceed into the MEL, and we
20 will come back to Ivor and Mr. Thomas in a minute.

21 WITNESS THOMAS: I can answer that question
22 now, if you wish, Mr. Chairman?

23 CHAIRMAN HALL: Yes, sir.

24 WITNESS THOMAS: This particular High-Z, Low-
25 Z shield was added on line number -- around about line

1 number 400. It was a concern about accuracy of the
2 FQIS.

3 There was a five volt, light-dimming circuit.
4 Mr. Hahn (sic) explained this yesterday. I will just
5 refresh it. I am not an electrical engineer, so this
6 will refresh your memory.

7 There was a five volt dimming system that for
8 EMI reasons was applying a signal onto the FQIS wiring
9 that was sufficient to cause a mild gaging system
10 inaccuracy to show up, and we wanted to correct that.
11 So, that was why that shield was added.

12 CHAIRMAN HALL: Now, does that have anything
13 to do with the fuel flow indicator on this? That
14 doesn't lead to the fuel flow indicator that was
15 fluctuating at all?

16 WITNESS THOMAS: No.

17 CHAIRMAN HALL: That is all I was interested
18 in. Okay, who's up? Mr. Wiemeyer, are we going to get
19 you to actually ask a question? Please proceed.

20 MR. WIEMEYER: Thank you, Mr. Chairman. The
21 next discussion is really not part of the aging
22 aircraft, per se. It has to do with what we call the
23 MEL, or minimum equipment list for an aircraft.

24 The general public becomes aware of items
25 that pertain to a minimum equipment list as a result of

1 an agent or a crew member generally making an
2 announcement that the flight is going to be delayed
3 because such and such has to be repaired.

4 The regulations permit certain items of
5 equipment to be inoperative on an aircraft, and that
6 aircraft may continue to operate for various lengths of
7 time with that equipment inoperative.

8 I would like to start out by asking Mr. Crow
9 if he would explain what the mechanism is with regard
10 to minimum equipment list and how the minimum -- excuse
11 me -- minimum equipment list was developed.

12 WITNESS CROW: I would be happy to address
13 that, Mr. Wiemeyer and Mr. Chairman. In 1964 the
14 Federal Aviation, through the Federal Aviation
15 Regulations, authorized the use of the minimum
16 equipment list for inoperable equipment -- instruments
17 and equipment. The regulation -- without trying to
18 sound bureaucratic, the regulation is FAR 121-628.

19 This contains all of the policy and some
20 procedures for implementing the policy. Basically, it
21 says, as you paraphrased, that a certificate holder --
22 and a certificate holder, Mr. Chairman, is an air
23 carrier, anyone that is involved in the business of air
24 transport, as a matter of fact.

25 But, they are authorized by this Federal

1 Aviation regulation to have certain instruments and
2 equipment inoperable as long as the FAA, through the
3 principal maintenance inspector, has issued as an
4 authorization to that air carrier operations
5 specifications D-95.

6 The operations specifications detail the
7 limitations of the MEL, the time limits for which
8 certain category items must be repaired, and it also
9 gives a provision for a continuing authorization for
10 MEL extension.

11 We issue this routinely to air carriers that
12 have demonstrated through the certification process
13 that they do, in fact, have all of the tools and
14 equipment, personnel and parts along -- at specific
15 points along its route to service its aircraft as a
16 certification requirement.

17 We will maintain that Op spec as long as that
18 continued authorization is met. Bureaucratically
19 speaking, that is FAR 121-105 as it applies to domestic
20 and flight operators.

21 The MEL concept is not a concept that is only
22 in the air carrier industry. For many years the
23 military has had delay discrepancy lists that
24 correspond with our MEL program. In some cases they
25 were more lenient, and in some cases they became more

1 aligned with our MEL procedures.

2 In 1978 the FAA, through the same process of
3 regulations, authorized 135 operators the same
4 privilege, and in 1991 they allowed single engine
5 operations with MEL privileges.

6 The process of developing an MEL starts with
7 the manufacturer and the proposed operators when a new
8 iteration of aircraft is being developed. The folk
9 that are going to be flying the airplane and the
10 manufacturer collaborate together using the best minds
11 they have to identify those systems that have the
12 redundancy to allow the aircraft to be operated to the
13 highest degree of safety in air transportation, such as
14 the Federal Aviation Act of 1958 described before it
15 was recodified.

16 In doing that and presenting to the Aircraft
17 Evaluation Group, and more specifically the Flight
18 Standards Flight Operations Evaluation Board, people
19 that have the ultimate responsibility for the
20 management and revision of the MMEL, master minimum
21 equipment list, they will provide that list that they
22 have prepared to the FOEB Chairman.

23 When it comes from the manufacturer and the
24 proposed users of that MMEL, it comes as a, quote,
25 "proposed master minimum equipment list." It is a

1 working document that will continue to be used by the
2 FOEB -- and I will use that acronym because it is
3 easier to say, Flight Operations Evaluation Board --
4 the manufacturer, interested operators, other parties,
5 specific people from the FAA and all three disciplines,
6 operations, maintenance and avionics, and they will
7 form a Board that will evaluate that proposed master
8 minimum equipment list.

9 Before that master minimum equipment list is
10 accepted and authorized -- approved and authorized for
11 use by the community, it must -- the Board must reach a
12 consensus of opinion on all items that are allowed to
13 be -- to be -- have equipment that is inoperable.

14 Once the FOEB approves that document, then it
15 is sent to the Air Directorate in Washington, it goes
16 on the MEL bulletin board and it is made available to
17 the general public. It is made available to all of the
18 air carriers where they can develop their own
19 individual minimum equipment list.

20 Now, the minimum equipment list that the air
21 carriers develop in cooperation with some of their
22 vendors and manufacturers, et cetera -- and this
23 information flows to them from the manufacturer.
24 Boeing, in fact, provides some support to its operators
25 of its airplane in the form of a dispatch deviation

1 guide that helps them identify maintenance and
2 operations activities that must be accomplished before
3 the airplane can be dispatched.

4 But, once this MEL is put together by the
5 operator, the principal maintenance -- principal
6 operations inspector has the final authority for that
7 MEL document. Before he or she would approve that
8 document, it would be a coordinated effort between all
9 three principals on there that have certificate
10 management responsibility for that air carrier.

11 Once they reach a consensus on the operator
12 and the certificate holder's MEL, then it would be
13 approved. At that point, as a Principal Maintenance
14 Inspector, I would initiate and authorize that operator
15 to use that minimum equipment list.

16 So, it has been around a long time, it is
17 developed in the interest of safety and to allow the
18 air carriers to have some dispatch reliability, and in
19 the highest interest of safety to operate the aircraft
20 it has system redundancy to perform and do the job it
21 is intended to do in air transportation.

22 MR. SWEEDLER: Excuse me, Mr. Crow. Could
23 you just give us some examples of the type of equipment
24 that can be inoperative and the airplane still be
25 allowed to operate?

1 MR. CROW: Yes, sir, I will try to speak to
2 that, Mr. Sweedler. The Boeing 747 master minimum
3 equipment list is a list of items of two -- excuse
4 me -- 299 pages. This includes -- this includes the
5 title page, the table of contents, the list of
6 revisions, the list of effective pages, a short summary
7 of each one of the changes that occurred to the MMEL,
8 the definitions which is quite extensive -- several
9 pages, eight or nine pages -- and the preamble to the
10 MEL.

11 The remainder of it is standard ATA Code 100
12 items that are listed as part of the systems on the
13 airplane that have been agreed upon by consensus that
14 can be deferred. There are many items.

15 MR. SWEEDLER: But, I was interested in an
16 example. Give us an example of a half a dozen items.

17 MR. CROW: One classic example would be a
18 boost pump. The fuel tanks have the redundancy. Most
19 of them have at least two boost pumps. Some may have
20 more depending upon the aircraft that you may be
21 talking about.

22 Because of the redundancy and because the
23 inerrant level of safety is still present with a boost
24 pump inoperative, that aircraft may be dispatched in
25 some cases, in accordance with its individual MEL and

1 the MMEL, with the boost pump inoperative.

2 There are other things. There are typically
3 three -- there are four classes, Mr. Sweedler, of items
4 by time category.

5 We have a Category A item which must be
6 repaired in accordance with the FAR, or any other
7 approved document that limits how long that item can be
8 inoperative.

9 We have a Category B item that will allow you
10 to operate with that particular item inoperative for 3
11 days. You have a Category C item that will allow you
12 to operate the aircraft with that particular item for a
13 period of 10 days. You have a Category D item that
14 would allow you to operate the airplane for 120 days.

15 I spoke earlier to a continuous authorization
16 for MEL extension, and those only apply to category B
17 and C items, because Category A items are defined by
18 the FAR or other approved documents. Category D items
19 are typically cabin convenience items and
20 administrative items.

21 MR. SWEEDLER: How about an example of a
22 piece of equipment that would fall in each of those
23 four categories?

24 CHAIRMAN HALL: Go ahead, and then let's move
25 on, Mr. Sweedler.

1 MR. SWEEDLER: Okay.

2 WITNESS CROW: Category D items would be
3 items that -- well, I am trying to make reference to
4 some that I really know about rather than trying to
5 draw some from the 747 MMEL.

6 Category A items might include those things
7 such as -- depending on a particular type of operation,
8 and I will try to keep this very simple. If a person
9 was going to operate the aircraft in a VFR environment
10 only, visual flight rules environment only, day time,
11 he may be authorized to operate that aircraft without
12 navigation lights, and the operative word is "may,"
13 depending on the individual MEL.

14 The Category B item could be -- depending on
15 the MMEL, could be a fuel system component. It could
16 be a piece of navigation equipment, or a Category C
17 item could be similar to the same.

18 Category D items typically put themselves in
19 the position of cabin convenience items or other items
20 that do not affect the airworthiness of the aircraft.

21 MR. SWEEDLER: Thank you, Mr. Crow.

22 WITNESS CROW: Yes, sir.

23 MR. WIEMEYER: Mr. Crow, who actually
24 develops the items on the minimum equipment list?

25 WITNESS CROW: The manufacturer and proposed

1 operators will develop the proposed master minimum
2 equipment list for delivery to the FOEB, and then the
3 FOEB has the responsibility and accountability for the
4 management and revision of that document.

5 MR. WIEMEYER: If you would, please, briefly
6 detail when a discrepancy is found the process that
7 that discrepancy goes through and who looks at it, who
8 makes decisions and who is responsible for the
9 application of a minimum equipment list.

10 WITNESS CROW: Well, typically the discovery
11 of discrepancies could come from two different places.
12 One, a pilot report which we refer to as pi-reps, or it
13 could be from a maintenance person working on an
14 airplane that is an in service airplane.

15 An in service airplane is an airplane that is
16 eligible for dispatch. An out of service airplane is
17 one that is in extended maintenance or inspection. So,
18 typically, if you have an in service airplane -- and
19 this is the only place that you would be concerned
20 about dispatchability -- it would typically come from a
21 pilot write-up, or from a maintenance discrepancy
22 discovered during one of the lesser checks, like a PS
23 Check or something of that sort.

24 Once the maintenance folk in debriefing with
25 the Captain and understanding the discrepancy, or on

1 their own initiative by finding a maintenance
2 discrepancy discovers that, then that information is
3 passed on through the maintenance control processes of
4 each air carrier.

5 It finally ends up in the Dispatch Center
6 where the aircraft dispatcher has the responsibility to
7 notify the flight crew that there is an item of
8 inoperative equipment or instruments, and that they
9 make a determination as a dispatcher in concert with
10 the flight crew and put that information on the
11 dispatch release.

12 It is incumbent upon the Captain of the
13 aircraft or flight crew member that when they do have
14 an item it is MEL'd. Generally, you will find that the
15 flight crews will check their minimum equipment list
16 that they are required to have with them either in
17 printed form or in another form to determine the
18 limitations of that MEL'd item before they depart.

19 MR. WIEMEYER: Okay, and my final question in
20 this area is what kind of latitude does the operator
21 and the principals for the FAA have in working within
22 the minimum equipment list? Can they change it and, if
23 so, how much? -- and that type of information is what I
24 am looking for.

25 WITNESS CROW: Well, first of all and most

1 foremost, the operator's MEL cannot be less restrictive
2 than the MMEL. The Principal Operations Inspector
3 having the final authority for the development and the
4 approval of the operator's MEL can within certain
5 limitations approve changes to the operator's MEL as
6 long as it is less restrictive than the master minimum
7 equipment list developed and approved by the FOEB.

8 MR. WIEMEYER: That brings up one final
9 question. The time limits that are placed on each
10 category, how are those arrived at?

11 WITNESS CROW: How are they arrived at?

12 MR. WIEMEYER: Yes.

13 WITNESS CROW: They are identified in the
14 preamble to the MMEL and the MEL. These are
15 longstanding provisions that have been in place, and I
16 would suggest to you without specific knowledge that
17 they have been there since the 1964 era.

18 MR. WIEMEYER: But, you don't know the
19 rationale behind their development?

20 WITNESS CROW: Well, because certain things
21 have more criticality than others, and it is important
22 that the air carriers take action to return the
23 aircraft to its full top certificated status at the
24 earliest opportunity.

25 An MEL item or a CDL item -- and I may

1 discuss that -- are actually a revision to the type
2 design, but no further approval is required in order to
3 do the -- to exercise the MEL provision.

4 MR. WIEMEYER: Okay, thank you. I would like
5 to turn the questioning back over to Ms. Eckrote now to
6 deal with the specifics of the aircraft involved in the
7 TWA accident.

8 MS. ECKROTE: Thank you, Norm. I have some
9 questions for Mr. Craycraft. Mr. Crow did answer some
10 of the questions I was going to ask. I would like you
11 to kind of more detail TWA's procedures as far as what
12 are your procedures when an item of equipment is
13 recorded inoperative, or a system is reported
14 inoperative?

15 WITNESS CRAYCRAFT: Well, the first procedure
16 is that if an item becomes inoperative, it is obvious
17 to the flight crew that they have something that is not
18 working properly, so they make an entry in the aircraft
19 log book. So, that is step one.

20 Step two, then, is it arrives at a station
21 and the maintenance personnel there have the
22 opportunity to either repair that item, if they have
23 the opportunity, or if they don't have the time to
24 repair it or the equipment to repair it, they may apply
25 the MEL application to it.

1 In the case of the accident aircraft, it had
2 four open MEL's on it. If you would like, I would just
3 go ahead and go through those items.

4 MS. ECKROTE: Yes, if you would, please, and
5 I think that will help Mr. Sweedler in identifying
6 exactly what an MEL is. Would you please identify it,
7 and then what the procedure or penalty is for each of
8 those items?

9 WITNESS CRAYCRAFT: Yes, sir. These -- three
10 of them happen to be Category C items, and Category C,
11 to remind you, is a ten calendar day item that the MEL
12 permits us to operate that aircraft. That is the time
13 limit.

14 Obviously, our intent is to restore the
15 aircraft to its full configuration at the first
16 opportunity, but many times we are on a very tight turn
17 schedule to get the airplane flying and we like to
18 allow the aircraft to an overnight maintenance where we
19 can conveniently repair the item.

20 The first item is a number three engine
21 thrust reverser malfunction, and that problem developed
22 on July the 7th at Tel Aviv, and they replaced a
23 pneumatic drive motor for the thrust reverser, and that
24 didn't fix it.

25 So, then the airplane then flew under the

1 auspices of the MEL, and then JFK replaced some flex
2 drives cables that had been sheared, and that still
3 didn't fix the item, so the item remained under the MEL
4 auspices. So, that was carried on.

5 But, the item obviously has to have the
6 concurrence of the maintenance coordinators to be
7 carried on an MEL. It is entered into our AMPS system
8 and is tracked by the AMPS, and that is what it is.

9 Now, with the thrust reverser there are some
10 penalties involved, and some interacting activities
11 that the reverser may be inoperative, and only one on
12 the aircraft of which there is four reversers,
13 obviously, and only one can be inoperative, and it can
14 only be inoperative provided the anti-skid system, the
15 auto-spoiler systems are operating normally and that
16 there is no damage on the thrust reverser which would
17 impair the structural integrity of the thrust reverser.

18 So, it isn't just a carte blanche that we can
19 go with the reverser inoperative. We have to do some
20 inspection and some procedures and assure that other
21 items on the airplane that could affect the function of
22 the aircraft are verified, also.

23 Likewise, they have to lock the thrust
24 reverser in the forward thrust position so that it
25 cannot inadvertently deploy and cause greater problems.

1 CHAIRMAN HALL: You might, if you wouldn't
2 mind, Mr. Craycraft, sort of tell us what the function
3 of the thrust reverser is, for those that might not be
4 familiar with it.

5 WITNESS CRAYCRAFT: Okay, I am sorry, I am
6 too used to airplanes. The thrust reverser is a device
7 on the engine that when the flight crew land the
8 aircraft and the gear are firmly on the ground, they
9 can extend reversers.

10 On our airplanes we only have fan reversers.
11 The airplane as it was originally delivered had fan and
12 turbine reversers, but we deactivated our turbine
13 reversers and just have the fan reverser. That is up
14 around the front end of the engine.

15 There is a sleeve that slides back around the
16 engine, and then there is blocker doors that come in
17 behind the fan air exit area and deflect the thrust of
18 the fan blades forward to reduce the forward speed of
19 the aircraft after the aircraft has landed. Is that
20 satisfactory?

21 Another item was an oil quantity on the
22 number three engine, and I forgot to say that was
23 number three engine on the thrust reverser. On an oil
24 quantity being inoperative, you have to service the
25 engine full with oil each time before the aircraft is

1 departed. So, that is the penalty that is involved
2 there, and that item was still an open item when the
3 aircraft left JFK. That is a C item, also.

4 Another item was the number three left
5 leading edge flap amber light stayed on when the
6 leading edge flaps were up, and that is a C item. That
7 was entered on July the 15th, and it was still an open
8 item. They had checked it and verified that the
9 leading edge devices were operating properly, but it
10 was just a light malfunction.

11 The other item is likewise a check -- a
12 Category C item, and it was on July 17th in Athens.
13 Going into Athens it was reported that the Captain's
14 weather radar indicator was inoperative. So, Athens
15 dispatched it, part of the MEL.

16 There was another weather radar on the
17 aircraft so that they did have weather radar coverage.
18 So, it was no operational penalty to dispatch with one
19 weather radar indicator inoperative.

20 We had one CDL item, and I don't know that
21 the CDL was described in the extent that the master
22 MEL, but that is -- configuration deviation list is
23 what a CDL is, and we had one item that on July the
24 4th, at Madrid we had a left hand canoe ferring for the
25 number two trailing edge flap.

1 When you -- that perhaps needs some
2 discussion of what is a canoe ferring, and if you have
3 seen a 747 and you look out there under the trailing
4 edge flaps, there is a huge device that looks like a
5 canoe. That is actually a ferring to cover the
6 structural aspects of carrying the flap carriage.

7 So, that is a canoe ferring is what it is
8 referred to, and it may be inoperative and -- or, may
9 be missing from the aircraft, and there is a runway
10 penalty for operating with that ferring off of there.
11 So, that, likewise, the crew would have to be advised
12 of these things, of every MEL item.

13 The instrument or indicator in the cockpit
14 that is inoperative has a placard on it so indicating
15 it is inoperative. There is a placard that is
16 installed on the aircraft log book that identifies what
17 the write-up actually was and why that is inoperative,
18 and then it is transferred to what is a deferred
19 maintenance page in the aircraft log book where it is
20 carried until it is corrected, and it is entered into
21 the AMP system which I mentioned earlier that tracks
22 all of the aircraft log items, including the ones that
23 are not corrected.

24 So, whenever an aircraft comes to a station
25 its work is performed. An open item AMPS sheet is sent

1 to that station. Then they have the opportunity to
2 work on it, or -- as manpower and material are
3 available to correct the items.

4 CHAIRMAN HALL: Very well, and one last
5 clarification. Maybe you could tell us again what a
6 CDL is versus an MEL and what the difference is.

7 WITNESS CRAYCRAFT: Configuration Deviation
8 List is what CDL is. That means that it is a -- it is
9 primarily structural ferrings and that sort of thing
10 where it is something that is deviation from the
11 configuration of the aircraft, whereas a master MEL --
12 that is the master MEL, MMEL -- and we use the term
13 master equipment and dispatch procedures book within
14 TWA for our maintenance people, and that is where we
15 have the list and the procedures for following the
16 utilized -- the MEL item.

17 The flight crews likewise have an MEL in
18 their flight hand book, but they don't have the
19 maintenance procedures that must be accomplished when
20 we dispatch an aircraft with an MEL item.

21 CHAIRMAN HALL: Okay, thank you.

22 WITNESS CROW: Mr. Chairman, I just want an
23 addendum to what Mr. Craycraft had said. For the
24 record, the CDL is not a part of the MEL. Many
25 operators place it there for the convenience of the

1 operators, but the CDL is actually an addendum to the
2 approved flight manual, and typically there is where it
3 is placed.

4 CHAIRMAN HALL: Thank you.

5 MS. ECKROTE: Mr. Craycraft, what procedures
6 are in place if the MEL item cannot be accomplished or
7 fixed in the appropriate time period?

8 WITNESS CRAYCRAFT: Within the procedures and
9 with the regulation it allows that in unusual
10 circumstances where the repair time limits described
11 cannot be met, it is possible to extend the repair
12 deadline under controlled conditions.

13 These time extensions, and I think Mr. Crow
14 referred to that, apply only to Category B and C items.
15 Before we consider an MEL extension item, it is our
16 Maintenance Coordination Group that has the
17 responsibility to assure that all reasonable efforts
18 and possibilities for correction have been extended
19 before we apply for extension of the MEL.

20 When I say apply for an extension, the
21 extension is really granted by one of our staff members
22 in the Maintenance Department. The requirement is to
23 provide that MEL extension item to the FAA within
24 twenty-four hours, upon which the FAA can then review
25 it, and when I say FAA, the Principal Inspector holding

1 the certificate, he reviews it and if he concurs with
2 it then we have the extension that we requested. He
3 has the prerogative of refusing the extension, at which
4 time the next time the aircraft lands, that's where it
5 sits until it is repaired.

6 MS. ECKROTE: Thank you. Mr. Crow, is there
7 anything you can add to that, or is that definition
8 adequate?

9 WITNESS CROW: I think Mr Craycraft is doing
10 an excellent job explaining that, and I appreciate
11 that.

12 MS. ECKROTE: Thank you. I have just one
13 last question for Mr. Craycraft. Who has the ultimate
14 responsibility to determine that the flight can be
15 conducted in a safe manner under the flight conditions
16 anticipated using the MEL?

17 WITNESS CRAYCRAFT: Well, ultimately it is
18 the Captain's responsibility to determine that there is
19 nothing on the aircraft that he -- when he takes the
20 aircraft, it is his responsibility to assure that
21 everything is there.

22 Of course, certainly maintenance is in no way
23 attempting to deter from safe operation of the aircraft
24 when we ask the crew to take an item on MEL.

25 MS. ECKROTE: So, in a case on the departure

1 of Flight 800 when we had four MEL items and one open
2 CDL item, you know, is it the Captain's responsibility
3 to also make sure that the interrelationship of those
4 systems won't interfere with the safe operation of the
5 flight?

6 WITNESS CRAYCRAFT: Yes. Of course, it
7 certainly is a maintenance responsibility to begin
8 with. We don't place the flight crew in that sort of a
9 situation, but ultimately, yes, it is the flight crew's
10 responsibility. He is the one that accepts the
11 aircraft. I might add, if he chooses not to take an
12 item under MEL, he has the prerogative also.

13 MS. ECKROTE: How does the flight dispatcher
14 fall within all of this, his responsibilities?

15 WITNESS CRAYCRAFT: I am not involved in the
16 flight dispatch aspect, so I really can't answer that.

17 MS. ECKROTE: Okay, thank you very much.

18 CHAIRMAN HALL: Now, Mr. Craycraft, I have
19 one question. On page 21 of the systems report at the
20 top of the page. I think we should clarify this. It
21 says, "After the accident on July 17th, 1996, a
22 mechanic reported to the National Transportation Safety
23 Board Operations Group Chairman that during the fueling
24 process for Flight 800 at JFK the fuel system shut
25 down."

1 "The mechanic reported that the circuit
2 breaker was pulled and the pressure fueling process was
3 continued. After the fueling was complete, the circuit
4 breaker was reset. The mechanic reported that an entry
5 in the aircraft maintenance log book was not made prior
6 to the departure of the flight."

7 I was wondering if you could tell us, since
8 this involved the fueling of the aircraft before the
9 accident flight, you know, if you could explain that
10 process to us. Was that something that should -- in
11 any way was impacted by the MEL, the CDL and should
12 there have been an aircraft maintenance log book write
13 up on that incident, or item?

14 WITNESS CRAYCRAFT: Yes, there should be,
15 because anytime there is a malfunction on the aircraft
16 it is supposed to be recorded in the log. That is the
17 first answer to your question.

18 Secondly, a reviewing on page 20, also it is
19 making reference to difficulty with the aircraft with
20 fueling, and without knowing specifically what happened
21 on that incident, but this -- I would go back into the
22 volumetric shut-off system which was described by Mr.
23 Taylor, I believe of Honeywell, since they make the
24 volumetric shut-off system.

25 But, that is really where the nub of the

1 problem was on this particular aircraft, that the
2 volumetric shut-off system has the capability of
3 shutting down the fueling on the aircraft. A fueler
4 will normally go out to the wing, open up the wing
5 panel, connect his hoses, of course statically ground
6 his fuel truck to the aircraft and to ground, and begin
7 fueling.

8 Power is applied to the wing fueling panel
9 when he opens the door so that he can open the fueling
10 valves to permit fuel to go from the fueling manifold
11 into the individual tanks. He has a switch on the
12 panel for each individual tank to control where the
13 fuel is going that he is putting into the aircraft.

14 The volumetric shut-off system was a device
15 that will shut the system down if he were not paying
16 close enough attention and tried to put too much fuel
17 in the airplane and -- but, it likewise has the
18 capability that if some malfunction occurs it could
19 shut it down at any time. I think that was what was
20 happening on this airplane. We were having some
21 difficulty in the vol shut-off system that was shutting
22 the fueling down.

23 CHAIRMAN HALL: The system, Mr. Vannoy or Mr.
24 Thomas, the wiring for that system, where does it run?

25 WITNESS VANNOY: I don't think either one of

1 us has the specific answer for you, Mr. Chairman.

2 CHAIRMAN HALL: Do you know, Mr. Swaim?

3 MR. SWAIM: Yes, sir, we will have that up
4 here in just a second.

5 (Slide shown.)

6 United States Information Agency. There we
7 go. The volumetric shut-off runs commonly between the
8 electrical compartment and the flight deck of the right
9 side at about station 360. That is the orange line
10 running up under the cockpit there. Up from there to
11 the cockpit.

12 CHAIRMAN HALL: Okay, well, does it run
13 parallel with any of these other things we have
14 discussed, the FQIS, the indicator for the four --
15 number four fuel flow and --

16 WITNESS VANNOY: In that short portion of the
17 run you have the blue line which is the fuel flow
18 wiring coming in from the wing. It goes to a computer
19 down there in the E&E which happens -- see that right
20 near the electrical equipment center which happens to
21 sit right near the volumetric shut-off computer, and
22 from there they are routed together up to the flight
23 deck through that orange wire -- that orange line.

24 CHAIRMAN HALL: Mr. Craycraft, as you alluded
25 to, on page 20 of that report it says that the aircraft

1 maintenance log book entries from July 1, '94 through
2 July 17th, '96, which is over a two-year period of
3 time, so I want to be sure -- indicate that "the
4 aircraft experienced several intermittent problems not
5 accepting fuel. In most cases the aircraft was
6 pressure-fueled and the action was deferred," and then
7 it lists those items.

8 Is this something that you have to deal with
9 in a maintenance situation, and is it related to the
10 age of the aircraft, or is this just a common problem
11 with the 747?

12 WITNESS CRAYCRAFT: Well, my first response,
13 it is not related to age because we have had -- at
14 various times have had difficulty with the volumetric
15 shut-off system on the aircraft. But, in terms of
16 comparing this aircraft to others in the fleet, I have
17 not made a comparison such as that, and there are
18 others, my compadres that are responsible for the fuel
19 quantity in that system.

20 CHAIRMAN HALL: Well, if there is anything
21 else that TWA would like to put on the record in that
22 regard, please supply it.

23 Mr. Thomas, what has been Boeing's experience
24 with this volumetric problem which Mr. Craycraft says
25 is -- I don't want to characterize what Mr. Craycraft

1 said exactly, but indicated was some problem?

2 WITNESS THOMAS: I am aware that occasionally
3 we do have problems with the volumetric top-off. There
4 was a question posed last night. The gaging system is
5 basically a mass indicating system. It is measuring
6 how many pounds of fuel on board the airplane.

7 Obviously, the tank itself has a finite
8 number of gallons of volume that it can take, so the
9 volumetric top-off system has to in effect convert the
10 mass indication or information coming from the FQIS
11 into a volume, and then keep track of how many volume
12 is in the tank and shut off the tank before the volume
13 is exceeded.

14 So, it is basically a conversion from pounds
15 of fuel going into the tank to how many gallons of fuel
16 is going into the tank.

17 CHAIRMAN HALL: So, the end of this is in the
18 tank itself?

19 WITNESS THOMAS: It is the gaging system.
20 There is a signal coming from the gaging system, which
21 is pounds.

22 CHAIRMAN HALL: Well, what could have caused
23 this problem? What are the various things that can
24 cause this thing not to work?

25 WITNESS THOMAS: I am not enough -- I am not

1 familiar with the exact details. It could be a --
2 there is a compensative problem, or a loss of signal
3 into the volumetric top-off system where it would say I
4 don't know how many gallons have gone into the tank,
5 therefore I will shut the system down.

6 It is a fail-safe system. It would say, if I
7 don't know what is going on, I will signal the system
8 to shut down, and the mechanics have the option of
9 bypassing the volumetric top-off system and basically
10 watching the gages very carefully and stopping the fuel
11 when they get the right amount manually. They have a
12 switch at the refueling station.

13 CHAIRMAN HALL: Okay.

14 WITNESS THOMAS: I don't know the details of
15 the specific event, but that is typically what --

16 CHAIRMAN HALL: What type of wire is used to
17 that system?

18 WITNESS THOMAS: I personally have -- I do
19 not know, sir.

20 CHAIRMAN HALL: Mr. Taylor, if you could find
21 out and provide that for the record, I would appreciate
22 it.

23 Any other questions from the Technical Panel
24 before we move to the parties?

25 MR. SWAIM: Yes, sir. Questions come up

1 about fuel indication discrepancies. It is -- in Ms.
2 Eckrote's Exhibit 11-A, pages 22 and subsequent, there
3 are several pages of write-ups on fuel flow indication
4 problems, gages that were placarded "inop" or gages
5 that were inaccurate, and I was wondering if Mr.
6 Craycraft could discuss what -- at least in those two
7 areas, what are the typical write-up and response as
8 far as if you have to placard it, and the typical
9 response for an inaccuracy of the fuel gage?

10 WITNESS CRAYCRAFT: I am sorry, Bob, I really
11 haven't had an opportunity to review the information.
12 I wasn't prepared to look at the fuel quantity aspect
13 of what the malfunctions were there.

14 I had looked at the fuel flow, since that has
15 been kind of a hot topic to discuss, and there was one
16 item where -- I am looking at page 24 of the report,
17 the bottom item where the mechanic quoted as suspecting
18 wiring.

19 But, if you continue on looking in that
20 report, that was -- a fuel flow transmitter was the
21 culprit there, the device -- the transmitting device on
22 the engine which caused the malfunction on that. So,
23 but in terms of saying typically what is a fuel
24 quantity, I would need to go back and review the data
25 and provide that to you.

1 MR. SWAIM: Would you please? We would like
2 to know how it is placarded. Actually, could you at
3 least discuss that side of it? If something is
4 placarded inoperative, if it is inaccurate and they
5 placard it, how would they do that?

6 WITNESS CRAYCRAFT: Well, the placard is put
7 on the gage at the flight engineer's station to
8 indicate that that unit is inoperative, and if I could
9 use the terminology that we use where for an ADL item,
10 for an aircraft item, that if the item is not
11 performing its intended function as it is supposed to
12 it must be considered inoperative.

13 So, even though it may be reading, and
14 reading inaccurate, but as far as our terminology is
15 concerned that is inoperative and we would placard it
16 that way and carry it per the MEL. I believe -- I
17 don't have that page of the MEL, but that only one
18 indicator per aircraft can be inoperative.

19 MR. SWAIM: Now, when they do that, do they
20 pull the circuit breakers, or somehow further sever or
21 cut off power to that system, or just simply put the
22 label "inop" on the indicator?

23 WITNESS CRAYCRAFT: I believe there is only
24 one circuit breaker that feeds the entire fuel quantity
25 system, so they could not pull the circuit breaker.

1 They would now only have to just leave that in and
2 placard that item.

3 MR. SWAIM: Very well, thank you.

4 CHAIRMAN HALL: Any other questions from the
5 Technical Panel?

6 (No response.)

7 If not, I believe we are back at Crane
8 Company Hydro-Aire. Do you have any questions for
9 these witnesses?

10 MR. WIEMEYER: Thank you, Mr. Chairman.
11 Crane has no questions.

12 CHAIRMAN HALL: Thank you. Now the
13 International Association of Machinists and Aerospace
14 Workers, the people that actually perform the work that
15 we have been talking about all afternoon, do you have
16 any questions for these witnesses?

17 MR. LIDDELL: Mr. Chairman, yes, we have just
18 one question for Mr. Swaim. Could you inform us as to
19 the age of the Philippines 737 that had the center tank
20 explosion? The relative age, not specific.

21 MR. SWAIM: Actually, I didn't work that
22 accident, but Mr. Haueter did. Maybe he can answer it.

23 MR. HAUETER: That airplane is approximately
24 six years old. It is a 737 300 series. It was fairly
25 new at the time.

1 MR. LIDDELL: Thank you.

2 MR. RODRIGUES: Mr. Chairman, Boeing?

3 CHAIRMAN HALL: Yes.

4 MR. RODRIGUES: I believe that it was six
5 months old, Tom.

6 CHAIRMAN HALL: Well, let's -- we have got
7 the report in here. Let's find out for sure. We don't
8 want to have any incorrect information here on that
9 matter.

10 (Pause.)

11 I thought I saw the 737 report in here,
12 didn't I, Deb? Where is it?

13 (Pause.)

14 Singapore accident, O'Hare accident, Madrid
15 accident.

16 MR. SWAIM: It should be in Exhibit 9(d).

17 CHAIRMAN HALL: Here it is.

18 (Pause.)

19 Well, this is your registration number E1BZG,
20 a Boeing 737 300 aircraft. Does Boeing have the
21 information on how old it is? I will be glad to accept
22 that if you do. I don't --

23 (Pause.)

24 I don't see it right here in the report.
25 This is, I might point out, a report of the Republic of

1 the Philippines Department of Transportation and
2 Communications Air Transportation Office. The National
3 Transportation Safety Board was a party to this
4 investigation. We did not conduct. We were not the
5 lead agency on the investigation.

6 (Pause.)

7 Well, let's -- we will come back and correct
8 the record on that so we are sure once we -- Mr. Pervis
9 is usually a fountain of knowledge. I am sure he must
10 know, either he or Mr. Donner.

11 Yes? Did you know, John, the age of the
12 aircraft?

13 MR. RODRIGUES: Less than six months.

14 CHAIRMAN HALL: Less than six months? Okay.
15 We will get the exact time on it, but Boeing represents
16 that it was -- the aircraft was less than six months
17 old when the accident occurred.

18 MR. LIDDELL: I have no further questions,
19 Mr. Chairman.

20 CHAIRMAN HALL: Thank you. Trans World
21 Airlines, Inc.? Captain?

22 CAPTAIN YOUNG: Thank you, Mr. Chairman. I
23 have a question for Mr. Swaim. The Alert Service
24 Bulletin that the Chairman was referring to I think in
25 the center tank refers to the jettison override pumps,

1 is that correct?

2 MR. SWAIM: It was a question for somebody
3 else and I didn't pull it out, so I don't have it.

4 CAPTAIN YOUNG: But, I think it does --

5 CHAIRMAN HALL: Yeah, I think it was, yeah.

6 CAPTAIN YOUNG: It refers to the jettison
7 override pumps and we did recover both of those pumps,
8 I believe, is that correct?

9 MR. SWAIM: Yes, we did. One did not have
10 the connector, though.

11 CAPTAIN YOUNG: Okay, but the pumps
12 themselves, did you find any deficiencies when you
13 inspected the pumps?

14 MR. SWAIM: Thanks to help here, yes, it is
15 that Service Bulletin, and we saw no evidence of that
16 sort inside the pump, inside the motor housing when we
17 took it apart.

18 CAPTAIN YOUNG: So, there were -- you found
19 no deficiencies, basically, with the pump then, I
20 assume?

21 MR. SWAIM: You are asking me a very broad
22 analytical question, or for a broad analytical
23 response.

24 CHAIRMAN HALL: Well, there is nothing in the
25 report right now that indicates we know anything is

1 wrong with the pump?

2 MR. SWAIM: At this point, that is correct.

3 CHAIRMAN HALL: Well, then, you know, if I am
4 going to bring it up and discuss it, Captain, I am glad
5 you pointed that out. I should have done that myself,
6 thank you.

7 CAPTAIN YOUNG: Yes, sir, and just you
8 mentioned on the record for the volumetric shut-off
9 procedure on page 21 of Mr. Swaim's systems report, it
10 discusses --

11 MR. SWAIM: It is Debbie Eckrote's.

12 CAPTAIN YOUNG: Oh, I am sorry, it is Debbie
13 Eckrote's report. I apologize, sir. It is on page 21.
14 It has the maintenance manual reference for the fueling
15 with the problem with the volumetric shut-off, so it is
16 in the record. Thank you very much.

17 CHAIRMAN HALL: Well, thank you. This was a
18 volume of material to go through, so is there anything
19 else that you want to clarify on this, because I want
20 to be sure -- I think Mr. Craycraft has done an
21 excellent job, but I -- is there anything else that you
22 have got, Captain?

23 CAPTAIN YOUNG: No, sir. I just wanted to
24 make sure it was in the record.

25 CHAIRMAN HALL: Okay, thank you. The Federal

1 Aviation Administration? Mr. Streeter?

2 MR. STREETER: Yes, Mr. Chairman. First of
3 all, for Mr. Crow. During your earlier testimony you
4 used -- you used the term "probable cause," and the
5 Chairman reminded me during the break that the term
6 "probable cause" has a very, very definite legal
7 meaning to the members of the Board, and it is
8 something that doesn't occur until out at the end of
9 the investigation.

10 Would you expect the FAA to respond quickly
11 to any confirmed NTSB finding that affects safety
12 regardless of the status of the probable cause?

13 WITNESS CROW: Well, the single word answer
14 to that is yes. I think the FAA Flight Standards Air
15 Certification Service would all respond immediately to
16 any recommendation that was appropriate and germane to
17 solving the problem and increasing safety in air
18 transportation.

19 MR. STREETER: All right, thank you sir, and
20 I would ask the Chairman if that --

21 CHAIRMAN HALL: That clarifies it for me.
22 Thank you, sir.

23 MR. STREETER: All right. Thank you very
24 much, sir. Mr. Taylor, Mr. Loeb asked a question
25 earlier about whether or not any Air Force -- he didn't

1 ask the question of you, but he asked whether any Air
2 Force airplanes had polyex wiring, and I was wondering
3 if you could answer that question?

4 WITNESS TAYLOR: Not to my knowledge. The
5 United States Navy used polyex.

6 MR. STREETER: Mr. Vannoy, speaking of --

7 CHAIRMAN HALL: I am just confused. So I can
8 understand this, doesn't the Air Force operate Boeing
9 military equivalents of the 737 -- some of these
10 equivalents, and are you saying there is different
11 wiring in the military version and the commercial
12 version?

13 WITNESS TAYLOR: The 747's that the -- first
14 of all, the polyex wire was used only on the 747
15 airplane. Some of it was installed as mission
16 equipment on AWACS airplanes, not as the aircraft wide,
17 but it was only used in the general fleet on the 747
18 airplane.

19 CHAIRMAN HALL: Are there any military Air
20 Force 747's that are classics that use a different type
21 of wiring?

22 WITNESS TAYLOR: I can't answer that
23 question. I don't know what has happened to --

24 CHAIRMAN HALL: Yeah, well, if you could just
25 find that out for the record. I just, you know.

1 WITNESS VANNOY: Mr. Chairman?

2 CHAIRMAN HALL: Yes?

3 WITNESS VANNOY: Bob Vannoy here. The 747's
4 used in the military, the -- like the E-4 airplanes,
5 the earliest line number they have is around 200, so we
6 stopped using the polyex wire sometime before that.

7 CHAIRMAN HALL: Okay.

8 WITNESS VANNOY: So, I think that is your
9 answer.

10 CHAIRMAN HALL: Good, thank you.

11 MR. STREETER: Mr. Vannoy, on the SSID's on
12 the 747's and other Boeing airplanes, I want to
13 clarify. Are these static documents or are they
14 updated as new information becomes available out of
15 your inspections?

16 WITNESS VANNOY: That is a true SSID item,
17 and actually it comes out of the document and is no
18 longer a part of the program and has its own Service
19 Bulletin and Airworthiness Directive and applies then
20 to all airplanes.

21 We also update those documents approximately
22 every couple of years, or depending on, you know, how
23 much has changed or whatever. With new techniques, new
24 alternatives for the operators that they request, and
25 sometimes new pieces of structure are added, and also

1 the sample fleet has changed, you know, and as
2 airplanes go out of service or no longer become
3 available for the inspections, we have to keep adding
4 in more airplanes to keep the sample at a reasonable
5 size, so there is a continual revision.

6 Right, every time we have a revision there
7 will be also a new Airworthiness Directive that
8 mandates that revision.

9 MR. STREETER: Thank you, sir. Mr. Slenski,
10 you showed one picture of a mechanical failure where
11 the insulation was worn off of the wiring. Do you know
12 if that was found during normal inspection procedures?

13 WITNESS SLENSKI: On that particular case,
14 actually I was present when we were doing some just
15 general inspection on aircraft wire and we came across
16 it in visual inspection.

17 MR. STREETER: Okay, and then I believe you
18 also mentioned that the majority of that type of damage
19 occurs -- what was it? -- within six inches of the
20 connectors?

21 WITNESS SLENSKI: Typically, and I think Mr.
22 Crow made references, too. It is within about twelve
23 to six inches of your connector because that is
24 typically where the connectors are moved most often
25 when you are moving avionics. It is handled.

1 MR. STREETER: All right, thank you, sir.
2 Mr. Craycraft, regarding that statement about most of
3 that damage being seen very close to the connectors,
4 would you normally expect that a TWA mechanic, when he
5 was installing or removing a piece of equipment, that
6 he would inspect the wiring around and near the
7 connectors?

8 WITNESS CRAYCRAFT: Yes, sir, I would expect
9 him to do that.

10 MR. STREETER: All right, and Mr. Crow, based
11 on your A&P background and working other certificates
12 and your military background, would you expect an A&P
13 or a military mechanic to examine those areas?

14 WITNESS CROW: I would expect an A&P mechanic
15 to look at those very significantly, because the more
16 opportunity you have for removal of those connectors
17 and to bend and to twist and move wire, perform
18 maintenance, the likelihood of damage increases.

19 So, in every case my expectation would be
20 that there would be a very good visual examination of
21 that wiring.

22 MR. STREETER: All right, thank you, sir.
23 Mr. Craycraft, if I could refer you to Exhibit 11(a),
24 if you have it there; that is, the Maintenance Group
25 Factual Report, and in that exhibit on page 30.

1 **(Pause.)**

2 The top of the -- about one paragraph down
3 there it has the paragraph -- at least on mine --
4 labelled paragraph 6 here and is the Aircraft
5 Maintenance Log dated July 7th.

6 WITNESS CRAYCRAFT: Yes.

7 MR. STREETER: Okay. Now, that goes to the
8 oil quantity, I believe, the oil quantity gage?

9 WITNESS CRAYCRAFT: Yes, sir.

10 MR. STREETER: And that is the MEL item that
11 you discussed earlier, and you mentioned that one of
12 the requirements of the MEL was to insure that the oil
13 tank was serviced completely prior to departure.

14 I am not familiar with TWA's MEL, but also in
15 the second paragraph in that section it states that in
16 addition that there can be no evidence of above normal
17 oil consumption or leakage, that the oil pressure
18 indicating system must be functional, that the low oil
19 pressure warning system must be functional and that the
20 oil temperature indicating system must be operating
21 normally and be monitored.

22 Assuming that that is all correct out of
23 TWA's MEL, is this -- is this just a sign of even
24 additional redundancy, and I know -- are all of these
25 items required in addition to topping off the oil tank?

1 WITNESS CRAYCRAFT: Yes, sir.

2 MR. STREETER: All right, thank you very
3 much. That is all I have, Mr. Chairman.

4 CHAIRMAN HALL: Boeing Commercial Airplane
5 Group?

6 MR. RODRIGUES: Boeing has no questions, Mr.
7 Chairman.

8 CHAIRMAN HALL: The Air Line Pilots
9 Association?

10 CAPTAIN REKART: The Air Line Pilots
11 Association has no questions, sir.

12 CHAIRMAN HALL: Honeywell, Inc.?

13 MR. THOMAS: Honeywell has no questions, Mr.
14 Chairman.

15 CHAIRMAN HALL: Thank you. Do any of the
16 parties have additional questions for these witnesses?

17 (No response.)

18 Does the Technical Panel have any additional
19 questions for these witnesses?

20 (No response.)

21 If not, Mr. Sweedler?

22 MR. SWEEDLER: I have no further questions,
23 Mr. Chairman.

24 CHAIRMAN HALL: Dr. Ellingstad?

25 DR. ELLINGSTAD: Mr. Vannoy, you had

1 introduced us to the notion of damage tolerance in
2 relation to structures and talked about the concept of
3 crack growth in structures in relation to that.

4 Is that same concept relevant to the systems
5 area, and is there an analogue in electronic systems to
6 crack growth?

7 WITNESS VANNOY: Well, I don't think there is
8 a relative similar process in the systems area. I
9 think in the systems area we do the very elaborate
10 checks, fault assessments and what we call FMEA
11 evaluations for each system to assure that things like
12 single failures will not be more than -- or, disable
13 one particular item.

14 So, there is an extensive analysis done on
15 systems, but it doesn't really have a similarity to
16 crack growth.

17 DR. ELLINGSTAD: But, no solutions that can
18 be achieved through some kind of inspection?

19 WITNESS VANNOY: I think in the systems area
20 the various attributes we have discussed here, the way
21 the systems are designed, the way they indicate their
22 faults and the constant maintenance puts them in kind
23 of a separate category, and I think the main area that
24 we have to focus on is where we have the latent faults
25 in systems, and by definition we can't tolerate those

1 and when we find them we fix them.

2 So, I think the area that we are getting into
3 now is we are going out and looking for latent faults
4 that we heretofore have not thought about. I think
5 that is really the next step, or that is the approach
6 that possibly has to be taken.

7 DR. ELLINGSTAD: Mr. Slenski, do you have a
8 comment on that area?

9 WITNESS SLENSKI: Well, the question, if
10 I understand it, can we apply some of these principles
11 using fault tolerant system design philosophy and -- I
12 think, as I mentioned in my presentation, many of our
13 concerns are the electromechanical type systems, and
14 you can apply some of these principles.

15 As an example, the solder joint. You can
16 predict crack growth in a solder joint. You can
17 predict oxide growth on contacts, on surfaces. So,
18 there are mechanisms we have.

19 It is very complex because you have the
20 electrical and structural aspects, and I don't think we
21 have arrived at the point where we can develop these
22 predictive models yet, although there is research in
23 those areas. So, it is possible if you consider all
24 these complex interactions.

25 DR. ELLINGSTAD: Okay, Dr. Dunn, are there

1 activities that the FAA is doing to further this kind
2 of research that Mr. Slenski is talking about?

3 WITNESS DUNN: I am not specifically
4 familiar with research that he has mentioned.

5 WITNESS SLENSKI: Well, if I can add, many of
6 our major contractors are working in these areas.
7 Obviously, I think it is more in the research arena at
8 this time. I think there is many organizations
9 supporting that research; the Air Force, all the
10 military.

11 I am sure other -- the air framing
12 manufacturers are working these areas, too, because we
13 are trying to apply these principles to arrive, and I
14 think Mr. Johnson mentioned a program yesterday called
15 the Avionics Integrity Program which was an attempt to
16 do what we are doing in the structures world in the
17 electronics world. So, there are these initiatives.

18 CHAIRMAN HALL: Well, I do have a general
19 concern, and I am not being, I hope -- I just -- of how
20 the information is transferred, and I have the
21 opportunity to meet with Administrator Garvey next
22 week, and I am going to ask her to look into being sure
23 that safety information that we get in the military and
24 in commercial that there is some bridges here of
25 transfer.

1 Now, you said you have been to the -- you
2 work very closely with the folks at Atlantic City and
3 you have been there. I just don't know whether there
4 is any type -- maybe there is no need for a formal
5 process there, but a Boeing aircraft equivalent 747 --
6 and I understand that the type of operation is
7 different, but there may be some things, you know, that
8 are learned that can be useful.

9 WITNESS SLENSKI: Well, Mr. Chairman, I
10 think, as I had mentioned previously, many of us sit on
11 committees together now as the military is adopting
12 more of the commercial standards. We sit in committees
13 together.

14 I know in the wiring installation and
15 materials committees, Boeing has represented all the
16 military services. The FAA even participates in those
17 meetings and -- so, we do have these technical
18 conferences. It is not just myself obviously. Many
19 Air Force, all military personnel in the various
20 disciplines participate in these various industry
21 associations and trade groups where we have that
22 exchange of information.

23 So, it seems to be working fairly well, and
24 it is probably improving because we are obviously
25 buying more commercial hardware off the shelf.

1 CHAIRMAN HALL: Dr. Dunn, you had a comment?

2 WITNESS DUNN: Yes, I would like to add a
3 little bit to what he said. I think the system could
4 be improved. I will say this. Perhaps some of the
5 things that we are doing in trying to address the White
6 House Commission on Safety and Security is to work more
7 closely with DOD and NASA in order to make sure there
8 is -- the research that they have done, this sort of
9 technology they have developed, as far as it relates to
10 wiring and also their experience base, that those items
11 are factored into our response that we expect to have
12 in June.

13 In addition, I would like to add that just
14 this year we started the first joint DOD, NASA and FAA
15 aging -- Aging Aircraft Conferences, and these are an
16 ongoing event. There will be another one next year.

17 In fact, there is -- I got a request at my
18 desk to provide a paper for that conference next year.
19 So, there is -- there is that going on, as well as
20 Mr. -- as George mentioned, there is also the aspect of
21 the committees that we all are participants on.

22 CHAIRMAN HALL: Thank you, Dr. Dunn. Will
23 you continue, please, Dr. Ellingstad?

24 DR. ELLINGSTAD: I have no further questions,
25 Mr. Chairman.

1 CHAIRMAN HALL: Okay. Dr. Loeb?

2 DR. LOEB: I just have a couple of quick
3 questions for Mr. Craycraft to try and take advantage
4 of your forty-one years of experience.

5 Were you here yesterday, sir?

6 WITNESS CRAYCRAFT: Yes, sir.

7 DR. LOEB: You know, in the maintenance
8 report, Exhibit 11(a), is a number of write-ups on the
9 reading lights and continuing lighting problems, and
10 then we had the discussion of the problem with the fuel
11 pump volumetric -- help me with this -- overflow shut-
12 off valve.

13 Then the problem, the situation with the
14 crazy -- I call it a fuel indicator. I think that was
15 the word of the crew -- or, fuel flow indicator. Your
16 forty-one years of experience is -- what would you do
17 as an Investigator to look into that matter to be sure
18 that had nothing to do with this tragedy?

19 WITNESS CRAYCRAFT: Well, first, sir, analyze
20 what each of the items is that it is talking about. I
21 will pick on reading lights for just a moment. They
22 are -- well, one of the reports I noticed in here was
23 just the fact that there was an awful lot of reading
24 light lamps that were burned out. So, obviously that
25 would have no affect on the thing.

1 Now, there was some comments on overhead
2 lights, and I believe the remark on the overhead
3 lights, they were on the left hand side of the
4 aircraft. So, there, again, I could discount them as
5 being involved because the one particular wire that was
6 referred to in the report, and I don't -- it gave a
7 specific wire number.

8 I think that is a very short wire, and it
9 only could have been routed in a very short distance to
10 where it could be in proximity to the fuel flow
11 indicator wire, as well as the valve shut-off wiring.

12 In terms of fuel flow, we have two
13 indicators, one on the flight engineer's panel and one
14 on the Captain's panel. There is no -- I have not read
15 the CVR transcript, so I don't know whether they are
16 making reference to both indicators, or not.

17 But, the same signal is driving both
18 indicators, so if only the one on the front panel is
19 acting up, then obviously it is not a signal that is
20 coming from the E&E compartment. It is somewhere
21 between the FE's panel and the forward panel. So,
22 there is a lot of analysis opportunity available in
23 looking at those circuits.

24 CHAIRMAN HALL: Well, the thing that struck
25 me on the lighting, and I have been on a 747 a number

1 of times and I know there is lots of those lights, is
2 just this frequency of over a hundred write-ups. Is
3 that something that you would consider unusual, or is
4 that fairly normal? I know there is a large number of
5 lights on the plane.

6 WITNESS CRAYCRAFT: Well, I think our
7 aircraft configuration is something like 34 and 404
8 passengers, so there is obviously a reading light for
9 every seat. So, you have quite a number of
10 opportunities there for reading light lamps to be
11 inoperative.

12 But, likewise, the multiplex system on the
13 747 can play tricks on you sometimes of turning lights
14 on when you don't want them and that sort of thing, and
15 that is strictly associated with difficulties within
16 the multiplex system.

17 CHAIRMAN HALL: Anyplace else we ought to be
18 looking, sir?

19 WITNESS CRAYCRAFT: I have been working very
20 diligently with Mr. Swaim and helping him in every
21 opportunity I can to look at these items.

22 CHAIRMAN HALL: Well, we appreciate your
23 cooperation. Just one last little item. Are you
24 familiar with the plane that we called, I guess, the
25 derelict airplane in 93105?

1 WITNESS CRAYCRAFT: I am familiar with that
2 airplane, yes.

3 CHAIRMAN HALL: Do you know why it was
4 removed from service?

5 WITNESS CRAYCRAFT: I believe it was an
6 economical decision that it was requiring some of these
7 major structural modifications and it wasn't within our
8 operational plan, it wasn't economically feasible to go
9 ahead and accomplish all those man hours of work on
10 that aircraft.

11 CHAIRMAN HALL: Okay. Any other questions
12 from the Board or the Technical Panel before I go to
13 the Panel?

14 MR. SWAIM: We have had a question about
15 polyex airplane used in -- I am sorry -- polyex wire
16 used in Naval aircraft in the systems Exhibit 9(c),
17 pages 54 to 58.

18 There are three letters from the Department
19 of the Navy, two of them to the Honorable James C.
20 Greenwood, House of Representatives, one to the
21 National Electronic Manufacturers' Association spanning
22 1982 to just three and a half months ago, 1980 -- 1997,
23 and they do show that some Naval aircraft, especially
24 F-14's have polyex wiring.

25 There were some difficulties which are

1 described in the letters, and for the most part they
2 were re-wired. So, I hope that answers that question,
3 or at least where to go find the answer for that
4 question.

5 CHAIRMAN HALL: Okay, anything else?

6 (No response.)

7 If not -- no?

8 MALE VOICE: No, sir.

9 CHAIRMAN HALL: No? Very well. Well, I
10 would like to do with this panel what I have done with
11 the others, and I don't know whether we will see any of
12 you all tomorrow, or later. Mr. Thomas will still be
13 appearing.

14 But, I would like to just go down the table,
15 and if there is anything that -- Mr. Vannoy, anything
16 else that you think should be contributed, or else the
17 Board should be doing in this investigation, or
18 anything that needs to be clarified, I would like to
19 give you the opportunity to do that, sir.

20 WITNESS VANNOY: Thank you, Mr. Chairman. I
21 would first like to thank across the room here the
22 members of the NTSB Technical Panel for their
23 participation today and for all their conduct leading
24 up to this hearing over the last couple of weeks. I
25 appreciate that.

1 I haven't had quite as much experience as
2 some of the members here on the panel, but I have been
3 in the business for quite a while, and during that time
4 I have had opportunity to participate in many
5 identification through the resolution of the problems.

6 In that activity my confidence has been
7 continually reinforced, not only at Boeing but by the
8 industry in our commitment to safety. As we have
9 discussed today, the older 747's require more
10 maintenance.

11 We know that they are a little less reliable
12 from the dispatch standpoint, but we contend that these
13 airplanes are not less safe, and you have our
14 commitment to continued airworthiness activities in
15 every respect on these airplanes. Thank you.

16 CHAIRMAN HALL: Thank you, Mr. Vannoy. Mr.
17 Thomas?

18 WITNESS THOMAS: A small comment in your
19 looking for sharing of information. Although we have
20 been prime in trying to understand -- from the aircraft
21 manufacturing side of the house we have been prime in
22 trying to help understand this airplane.

23 We have reached out to the other airplane
24 manufacturers across the world and asked them to help
25 us. Even at this time last year when we realized

1 identifying the cause was going to be a long effort we
2 started dialogue with Air Bus.

3 Even though we are on the competitive side of
4 the world where we are forever arguing, as far as
5 safety is concerned we have met with Air Bus, we have
6 met with McDonnell, we have met with Lockheed, and we
7 spent a lot of time going through an awful lot of
8 detail on how we design our airplanes and sharing that
9 information.

10 I think it is appropriate to recognize that
11 the industry has really come together to try and
12 understand this one.

13 CHAIRMAN HALL: Well, thank you very much,
14 Mr. Thomas. Mr. Taylor, I must tell you I am impressed
15 to meet anyone with thirty-seven years of experience as
16 a wire expert, and I appreciate your contributions here
17 today in helping make this understandable for the
18 Chairman and for those who are observing.

19 MR. TAYLOR: Thank you. One of the things
20 that I have noticed about working at Boeing and with
21 other aircraft manufacturers is a continued commitment
22 to safety and their integrity in that regard.

23 I can assure you that when this hearing is
24 over our commitment to safety will continue as actively
25 and as continuously as it has in the past. When I

1 leave here -- tomorrow, I hope -- when I leave here I
2 will go back and I will continue to do the best I can
3 with my co-workers to make sure that the wire that we
4 have is the best wire, that the condition of the wire
5 on the airplanes that we service we know about, and
6 when we see something that needs action we will take
7 appropriate action, and we will work with other people
8 within the industry to make sure they know what we know
9 and that we know what they know.

10 CHAIRMAN HALL: Thank you very much, Mr.
11 Taylor. Mr Craycraft, you have done an excellent job
12 of representing Trans World Airlines, Inc. Your
13 comments, please?

14 WITNESS TAYLOR: I would just like to add for
15 the record I don't know as it had ever been drawn out
16 before, but we have Boeing field service
17 representatives on site at TWA that provides a free
18 flow of information between TWA and Boeing and other
19 air carriers, other manufacturers also, so that it
20 isn't a difficult situation for us to relay any
21 difficulty we have with the aircraft.

22 Certainly I want to express an opinion that
23 it is our number one objective in the Maintenance
24 Department to supply a safe, reliable aircraft for our
25 flight crews to carry the passengers.

1 CHAIRMAN HALL: Well, thank you very much,
2 Mr. Craycraft. Mr. Slenski?

3 WITNESS SLENSKI: Mr. Chairman, I will take
4 an opportunity here to answer one of the questions from
5 yesterday. We had an issue about bonding inside of
6 fuel tanks. We do have active programs, depending on
7 the type of aircraft, to phase inspection on the actual
8 bonding connections. It just depends on the type of
9 aircraft.

10 CHAIRMAN HALL: So, the three inches we were
11 talking about --

12 WITNESS SLENSKI: My understanding is we have
13 gone more to a performance requirement on that where we
14 are now actually specifying an energy level and a
15 voltage level.

16 CHAIRMAN HALL: Well, you might share that
17 information with the FAA, if they don't all ready have
18 it.

19 WITNESS SLENSKI: I think as far as the fuels
20 question, I think in the next panel there might be an
21 opportunity to answer that question, I think, as far
22 as -- the question was, why did we change from JP-4 to
23 JP-8. I think that will be answered there.

24 The other issue I just wanted to point out,
25 too, that I have shown some failures. I don't want to

1 give the impression that we have a wiring problem in
2 the Air Force.

3 Many of those photos I had shown were over a
4 fifteen year period, and we are aggressive in trying to
5 understand why we had a failure, and fix the problems,
6 and I don't really see that we have a major problem
7 with wiring. It is an issue and it is a concern, and I
8 think, as we have mentioned here, aging electronics is
9 a concern that we need to look at more carefully as
10 avionics becomes more complex.

11 CHAIRMAN HALL: Well, let me state again for
12 the record that on each -- the 747 has an excellent
13 safety record. I think this was the first accident for
14 Trans World Airlines in a long period of time, and the
15 commitment that we and the cooperation we have received
16 in this investigation, generally speaking, from all the
17 parties has been outstanding and I -- the Chairman
18 certainly has no question over the commitment of the
19 individuals of the organizations involved in this
20 investigation.

21 Because so much attention and publicity has
22 been given to this investigation, I want the American
23 people to know all of the things that are being done.
24 I hope that it in no way reflects -- as we go through
25 all of the possibilities, all the things that we found

1 in the investigation, it is important for me to point
2 out that we do not have an ignition source in the
3 center tank that we have been able to identify as a
4 probably cause of this accident.

5 That work will continue, but this is part of
6 the investigation process, and I appreciate your
7 comments very much because I want to be sure the record
8 is clear on each and every opportunity in that regard.

9 Mr. Crow?

10 WITNESS CROW: Yes, sir. Thank you, Mr.
11 Chairman. I think in closing I would like just to
12 reiterate that the FAA Flight Standards Service
13 continues to provide professional leadership and
14 surveillance of the air carriers that are currently
15 certificated in operating not only in the U.S., but
16 worldwide.

17 We continue to pledge to the American public
18 that we will continue to try to do the right thing and
19 to serve the public trust at every opportunity, which
20 includes those revisions and those things that need to
21 be done to insure the highest degree of safety. Thank
22 you.

23 CHAIRMAN HALL: Thank you. Dr. Dunn?

24 WITNESS DUNN: Yes, as Bill said, I would
25 like to reiterate the fact that we are -- while we have

1 a system in place that we think adequately addresses
2 continuing airworthiness and aging systems, we are
3 always looking to improve that process.

4 We don't have all the answers, and I think a
5 lot of the issues that were addressed here at this
6 Systems Panel are important for our continuing review
7 of our processes, and of course we will be using the
8 information we have gained here in our investigations
9 over the next year. Thank you.

10 CHAIRMAN HALL: Thank you, Dr. Dunn.

11 As you may know, the Chairman was honored to
12 have been appointed and serve on the White House
13 Commission on Aviation Security and Safety, and I was
14 in that meeting during a number of discussions where
15 General Lowe, who is a member of that commission, a
16 distinguished Air Force General and I believe Air
17 Combat Commander, was one who was very strong in
18 raising the issue of us looking at aging systems. This
19 was because of his personal experience in going out and
20 looking at a lot of the Air Force fleet.

21 I don't know, obviously, but I am glad to see
22 the FAA is looking at that. We will look forward to
23 your report in June in that regard, and I understand
24 you have got that work in progress and that will be
25 coming to us.

1 Very well. Do we want to start the next
2 panel today? What is the preference, Mr. Dickinson?
3 Do the parties have any preference? Do we want to try
4 and get into the Ignition Sources today and take about
5 an hour or two and then finish it up in the morning?

6 (No response.)

7 Well, let's do this then. Let's just say
8 that what we are going to do is we are going to start
9 the Ignition Sources Panel -- now, Ignition what? I am
10 sorry, the Flammability Reduction Panel at 4:00, and
11 then we will go for two hours, and we will recess at
12 6:00 p.m. and reconvene in the morning at 9:00 to
13 complete the work in that panel.

14 I hope that since this is such an important
15 panel that none of our distinguished panel
16 participants, or staff, or others feel compressed by
17 the fact that we have been sitting here for four days
18 under these attractive lights that you are going to not
19 get all the information that we need to get out on the
20 record.

21 I thank everybody, again, with this panel,
22 and we stand in recess until 4:00 p.m. Off the record.

23 (Whereupon, a brief recess was taken.)

24 CHAIRMAN HALL: On the record. I would ask
25 the observers in the hall to please take their seats.

1 We are going to reconvene this National Transportation
2 Safety Board public hearing that is being held in
3 conjunction with -- in connection with the
4 investigation of the aircraft accident TWA Flight 800
5 that occurred on July 17th, 1996.

6 Mr. Dickinson, would you please introduce the
7 next panel, which I believe is the panel on
8 Flammability Remediation?

9 MR. HAUETER: Mr. Chairman, before the panel
10 starts, I would like to correct the record on the
11 Philippines Airlines.

12 CHAIRMAN HALL: Oh, very well. We have
13 information. Go ahead.

14 MR. HAUETER: Yes, the airplane was
15 approximately seven months old at the time of the
16 explosion. It had accumulated 1,358 hours and 1,778
17 cycles, or take-offs and landings. So, I wanted to
18 correct the record.

19 CHAIRMAN HALL: It was how old? I am sorry.

20 MR. HAUETER: Approximately seven months.

21 CHAIRMAN HALL: Seven months old. Very well.

22 MR. HAUETER: Thank you, sir.

23 CHAIRMAN HALL: That is good to have that on
24 the record.

25 WITNESS DUNN: Would the Remediation Panel

1 please stand, please? Actually, it is the Flammability
2 Reduction Panel. Please raise your right hand.

3 (Witnesses comply.)

4 Whereupon,

5 MR. TOM McSWEENEY, MR. HARDY TYSON, DR. ROBERT BALL,
6 MR. RALPH LAUZZE, MR. IVOR THOMAS, CAPTAIN STEVE GREEN
7 were called as witnesses by and on behalf of the NTSB,
8 and, after having been first duly sworn, were examined
9 and testified on their oath as follows.

10 MR. DICKINSON: Thank you. Please be seated.
11 This Reduction Panel consists of Mr. Tom McSweeney,
12 Hardy Tyson, Dr. Robert Ball, Ralph Lauzze, Ivor Thomas
13 and Captain Steve Green. They will be questioned --
14 initially presented with a presentation by Mr. George
15 Anderson and questioned by Bob Swaim and Dr. Dan Bower.

16 Mr. George Anderson is an NTSB Aerospace
17 Engineer with Aircraft Accident Investigations, and he
18 had two years with the Safety Board. His prior
19 experience in private industry and the Air Force is in
20 mechanical test engineering, aircraft design and
21 overhaul, aircraft performance, human factors, a
22 development engineer for the GAU-830 MM Canon Flight
23 Test Transport, an instructor pilot and a flight
24 examiner.

25 He has a B.S. in Physics and Electrical

1 Engineering from the U.S. Air Force Academy, an M.S. in
2 Aeromechanical Engineering from the Air Force Institute
3 of Technology, Engineering Management at Naval Post
4 Graduate School and a U.S. Air Force Aircraft Accident
5 Investigation School at Southern -- the University of
6 Southern California.

7 Mr. Tom McSweeney, please raise your hand,
8 please.

9 (Witness complies.)

10 He is the Director of Aircraft Certification
11 Service for the FAA. He has been with the FAA for
12 twenty-three years, previously served as the Deputy
13 Director of Aircraft Certification Service and has held
14 managerial positions at the FAA in several areas,
15 including the Office of Airworthiness and the Office of
16 Aviation Standards.

17 He has a Bachelor's degree in Aeronautical
18 Engineering from Northrup U, and a Master's degree in
19 Aeronautical Engineering from California Institute of
20 Technology.

21 Mr. Hardy Tyson, please identify yourself.

22 (Witness complies.)

23 Thank you. A Mechanical Engineer, Naval Air
24 Warfare Center in China Lake, California. He has been
25 at China Lake for fourteen years, and his area of

1 expertise is in the Aircraft Combat Survivability
2 focused in the area of fuel system protection for the
3 Navy and Marine Corp. front line fighter and attack
4 aircraft.

5 This entails ballistic testing of aircraft
6 and their components with threats likely to be
7 encountered in combat for the purpose of determining
8 their design vulnerabilities and identifying protection
9 requirements.

10 He is actively involved in research and
11 development for vulnerability reduction concepts, and
12 currently the Navy's lead live fire test engineer for
13 the F-18 program. He has a Bachelor's in Mechanical
14 Engineering.

15 Dr. Robert Ball?

16 (Witness raises his hand.)

17 Thank you. Distinguished Professor,
18 Department of Aeronautics and Aeronautics, the Naval
19 Post Graduate School in Monterey, California.
20 Aeronautics and Astronomics.

21 He is thirty years at the Naval Post Graduate
22 School, and in 1976 he began development of an
23 educational program in Aircraft Combat Survivability.
24 He has conducted courses for NATO and the governments
25 of Canada and Greece.

1 In 1989 he established an AIAA Technical
2 Committee on Survivability. He has a Bachelor's in
3 Civil Engineering, a Master's degree in Civil
4 Engineering and a Doctorate in Structural Mechanics.

5 Dr. Ralph Lauzze, please -- I am sorry about
6 pronouncing your name there, but he is the Director of
7 Live Fire Test and Evaluation at the Air Force Research
8 Laboratory.

9 CHAIRMAN HALL: How is that pronounced, sir?

10 WITNESS LAUZZE: It is not doctor, but it is
11 Lauzze.

12 MR. DICKINSON: I am sorry.

13 WITNESS LAUZZE: That's all right.

14 CHAIRMAN HALL: That's okay, we have had
15 enough doctors here.

16 WITNESS LAUZZE: One out of three isn't bad.

17 (Laughter.)

18 MR. DICKINSON: He directs testing and
19 evaluation for the Air Force Aircraft and Development
20 including the C-17, B-1, F-22 and C-130. Joint Test
21 Director of the OSD sponsored Live Fire -- Joint Live
22 Fire Program. He oversees the vulnerability live fire
23 evaluations of current front line fielded aircraft.

24 He is the current Chairman and Air Force
25 principal member to the Tri-Service Joint Technical

1 Coordinating Group on Aircraft Survivability. He has a
2 B.S. and an M.S. in Mechanical Engineering.

3 Mr. Ivor Thomas; he is on our fourth panel
4 today and this week, so I won't go over his
5 qualifications. They are on our NTSB web site.

6 Captain Steve Green, who is an active member
7 of the TWA investigation representing ALPA. He is a
8 pilot flying for TWA, he has been with TWA for nine
9 years and he is currently flying the 767. He is
10 currently the team leader for ALPA's In Flight Icing
11 Certification Project. He also has a B.S. in Aviation.

12 Mr. George Anderson, I will --

13 CHAIRMAN HALL: Before Mr. Anderson begins I
14 would like to make note that among this panel are
15 members of the Department of Defense who have
16 contributed timely and highly professional support in
17 many areas of this investigation.

18 Today we have asked the Department of Defense
19 to assist us by providing expert witnesses for this
20 panel. These witnesses were selected to present an
21 overview of some of the methodology used by the
22 military services to design airplanes that can survive
23 in hostile environments. Over the years these designs
24 have saved the lives of military men and women in both
25 combat and peace time incidents.

1 I think we will come to understand that the
2 concept of hostile environment includes not only
3 intentional acts of violence using weaponry, but also
4 the extreme operating conditions that are imposed on
5 airlines by the myriad forces of nature.

6 In spite of the advance technology and
7 sizeable resources that we enjoy in our country, we
8 have yet to design an airplane that can survive all of
9 nature's extremes. In the case of fuel tank hazards,
10 we strive for progress and improvement while
11 recognizing that no system can eliminate all risk.

12 So, we are going to be looking now -- turning
13 to, you know, what can be done, and I am really looking
14 forward to hearing from this panel. So, please
15 proceed.

16 Mr. Anderson, it should be noted that you
17 have a long and distinguished career with the Air
18 Force, and have been with the Safety Board in two
19 years. So, I hope there is no conflict of interest in
20 your questioning these folks from the Air Force. Is
21 that all right? You will be sure to give them a hard
22 time, won't you?

23 MR. ANDERSON: I am sure we will be able to
24 do that. Thank you, sir.

25 Chairman Hall and Members of the Board of

1 Inquiry, the subject of this panel is Fuel Tank
2 Flammability Reduction. These witnesses will give us
3 an overview of what measures are currently being taken
4 and what measures could be taken to reduce fuel tank
5 flammability.

6 Our investigation has examined a number of
7 possible methods for reducing or eliminating fuel tank
8 flammability, including inerting, fuel tank heating and
9 cooling, ullage dilution and aircraft design changes.
10 We have also reviewed some technologies currently used
11 by the military.

12 We will discuss with these panel members the
13 benefits and other possible ramifications of
14 implementing various methods for either reducing or
15 eliminating fuel flammability in civilian, commercial
16 aircraft. We will also discuss any efforts that are
17 currently underway to achieve this goal.

18 Good afternoon, Dr. Ball.

19 WITNESS BALL: Good afternoon, Mr. Anderson.

20 MR. ANDERSON: We are starting off with you,
21 and I would like you to describe for us, if you would,
22 the aircraft combat survivability discipline that you
23 so ably teach at the Naval Post Graduate School.

24 WITNESS BALL: Mr. Anderson, I would like to
25 thank you for the opportunity to do this. We are a new

1 discipline. Let me start off by examining how an
2 aircraft can survive in combat.

3 There are basically two ways. One, if the
4 aircraft can avoid being detected, tracked, engaged and
5 eventually hit by a weapon it will survive. If that is
6 not possible, if an aircraft does get hit, it will
7 survive if it withstands the hit. So, we survive by
8 not getting hit, or if we get hit we withstand that
9 hit.

10 May I have the first slide, please?

11 (Slide shown.)

12 The inability of the aircraft to with -- to
13 avoid being hit, or the likelihood it is hit, we call
14 aircraft susceptibility. The more susceptible an
15 aircraft is, the more likely it is going to be hit in
16 combat. The inability of the aircraft to withstand
17 that hit, or the more likely it is killed given that it
18 is hit, we call aircraft vulnerability.

19 Aircraft susceptibility and vulnerability are
20 bad attributes of aircraft. We like to design them out
21 of the aircraft. We try to reduce them as much as
22 possible.

23 If we look at the survivability equation that
24 I have listed at the bottom of the slide there
25 (indicating), survivability -- that is, the likelihood

1 you will survive a mission or an engagement with a
2 weapon -- survivability is one minus the product of
3 your susceptibility times your vulnerability.

4 This is a very powerful equation. It can be
5 used in all parts of life; driving automobiles,
6 crossing the street, whatever. You don't want to get
7 hit, but if you get hit you don't want to die. If you
8 can reduce that product to susceptibility and
9 vulnerability, you can increase your survivability.

10 You asked for what survivability is about.
11 That is what we are about. We are a new discipline, a
12 formal discipline in which we have an organized
13 process, part of the systems engineering process, for
14 examining an aircraft design to reduce its
15 susceptibility and to reduce its vulnerability.

16 Now, how do we do this? Well, if you look at
17 the susceptibility part, we can reduce susceptibility
18 with stealth. We design aircraft to be difficult to
19 detect by the enemy radar sensors and the infrared
20 sensors visually and orally.

21 We can carry on board electronic counter
22 measures which deceive enemy weapons. We select
23 effective tactics, like attacking at night. We use
24 long range precision guided weapons to increase our
25 survivability by decreasing our likelihood of being

1 hit.

2 When we look at the vulnerability side, we
3 want to withstand the hit. We don't want fuel tank
4 explosions. We are concerned far more than a .2
5 millijewel of energy. We are concerned with high
6 explosive rounds going off inside our fuel tank. It is
7 a big problem to us.

8 We have got to design that aircraft to be
9 rugged and to take a hit and continue to fly. We do
10 that by designing in protection for the fuel system,
11 the flight control system, the crew systems and all the
12 other systems on the aircraft that are providing
13 essential functions that we need to continue to fly.
14 That is us.

15 MR. ANDERSON: Excuse me. Dr. Ball, has this
16 discipline evolved over time? Could you describe
17 basically how it started and where it is today,
18 roughly?

19 WITNESS BALL: Yes, as I mentioned earlier,
20 we are a relatively new design discipline. Aircraft
21 have been designed to survive in combat on a -- I would
22 say a haphazard basis, depending upon the emergency.
23 World War I, World War II, you are all familiar with
24 the B-17 aircraft. Ten people on board, eight people
25 were firing guns.

1 That was susceptibility reduction, trying to
2 destroy the enemy fighters before they could hit the B-
3 17, although the B-17 was designed to be rugged and
4 take hits and fly with holes in it. That was
5 vulnerability reduction.

6 It has been around, but starting in Southeast
7 Asia the United States went into that war flying
8 aircraft that were developed after the Second World War
9 when the jet engine came along and nuclear warfare was
10 threatened, and aircraft were not specifically designed
11 to fight in the environment we found ourselves in in
12 Southeast Asia in the 1960's.

13 As a result of having to use aircraft not
14 designed to survive in that environment, the United
15 States lost over 5,000 fixed wing and rotary wing
16 aircraft in that roughly ten year period.

17 As a result of this large number of aircraft
18 killed, the individual services established
19 survivability organizations within their services,
20 offices that dealt with susceptibility and
21 vulnerability.

22 In 1971 the services together established the
23 Joint Technical Coordinating Group for Aircraft
24 Survivability, more fondly known as the JTCG/AS,
25 another acronym for you. It is a great organization

1 that has been very effective in establishing
2 survivability as a design discipline. That was one of
3 their goals, establish survivability as a design
4 discipline.

5 Now, as was mentioned, I am an educator. I
6 was educated in structural mechanics. In the 70's I
7 was asked to work on a problem called hydrodynamic dram
8 in fuel tanks. Hydrodynamic dram is a problem in which
9 a fuel tank can be ripped apart as a bullet or fragment
10 propagates through the fuel in the tank. So, fuel
11 tanks are vulnerable not only to explosions, but they
12 are vulnerable to hydrodynamic dram.

13 When I learned about JTCG/AS and their goal
14 to establish survivability as a design discipline, I
15 thought to myself, every discipline has educated
16 scientists and engineers in that discipline. People
17 are taught how to do something, how to design a -- I
18 was taught how to design a structure.

19 So, I felt that the discipline needed an
20 educational program. So, the Joint Technical
21 Coordinating Group sponsored me to develop an
22 educational program at the Post Graduate School, and in
23 1977 we developed our first graduate level course in
24 survivability, and I believe it was the first course
25 that was ever developed. We also developed a one week

1 short course. We have had over 3,600 people take one
2 or both of those courses.

3 In 1985 the AIWA published the Survivability
4 Text Book under sponsorship of JTCG/AS and my
5 authorship. A little plug here, if you will.

6 (Next slide shown.)

7 Thank you. It was left out of my bio, so I
8 thought I better slip this in. By the way, I receive
9 no royalties for this. It is a -- it is a best seller.
10 "Fundamentals of Aircraft Combat Survival, the Analysis
11 of Design," and I might add it is being translated as
12 we speak into Chinese.

13 CHAIRMAN HALL: If somebody was interested in
14 getting a copy of that book where could they get it,
15 Dr. Ball, since you mentioned it?

16 WITNESS BALL: AI -- well, actually, Mr.
17 Hall, I will give you a personal copy. But, AIAA. I
18 will sign it, too. AIAA.

19 Another major event was in 1987. Congress
20 felt that the military services were perhaps not
21 adequately testing for the vulnerability of their
22 systems, and they wrote the Live Fire Test Law.

23 This test law requires that all covered
24 weapons systems, platforms and weapons, be tested to
25 determine, in the case of the platform, their

1 vulnerability by firing weapons likely to be
2 encountered in combat at fully configured full scale
3 platforms, such as a full scale aircraft, up and
4 running and carrying ordinance. If that testing turns
5 out to be unreasonably expensive and impractical, a
6 waiver may be granted with the submission of an
7 acceptable alternate test program.

8 As a result of all of this increased
9 intention on survivability, the aircraft that were
10 developed through the 70's and 80's were far more
11 survivable than those that we fought in with in
12 Southeast Asia.

13 When we entered into Desert Storm, we only
14 lost 38 aircraft out of 100,000 Sortis. That is a loss
15 rate significantly less than we had had in Southeast
16 Asia, significantly less. Our aircraft were designed
17 to survive, and combat data proved that they did.

18 We are now to the point where basically --
19 and military aircraft today is not designed without a
20 major consideration of its survivability. If you look
21 at the Joint Strike Fighter, the most recent program in
22 the tactical air world in the Department of Defense,
23 the Joint Strike Fighter, there are four what they call
24 pillars of which this aircraft is built upon;
25 affordability, lethality, supportability and

1 survivability.

2 So, and since we have come a long way -- and
3 I think that it has been beneficial to the United
4 States that we -- we win wars with these aircraft.

5 MR. ANDERSON: Thank you, Dr. Ball. How does
6 the discipline, the survivability discipline, evaluate
7 the fuel tank explosion problem? I think it is useful
8 at this time to -- because we have the background in
9 the academic discipline to focus on that problem and
10 perhaps go into it to some depth.

11 CHAIRMAN HALL: I wanted to mention here, Mr.
12 Anderson, so that -- Dr. Ball I am sure is aware that
13 the Chairman of the Oversight Committee for the NTSB
14 and the Senate is Senator John McCain, who does an
15 outstanding job and was one of the, I guess, 5,000
16 aircraft that was lost in Vietnam.

17 I have got several letters from people
18 talking about the phone system that was in place, I
19 guess, or used during that period, which I guess we are
20 going to get into. But, both Senator McCain and
21 Chairman Jim McDuncan, who is -- I grew up with in
22 Knoxville, Tennessee is the head of our House Aviation
23 Subcommittee.

24 Both of them have, I think, expressed an
25 interest in this area and being sure that we are, you

1 know, exchanging all the knowledge and information.
2 So, again, I appreciate your presence here, and
3 continue.

4 WITNESS BALL: Thank you. Okay, to your
5 problem, the fuel tank vulnerability problem. It is
6 also our problem. When we have a vulnerability
7 program, as we do on every aircraft, there are three
8 tasks that we have to perform.

9 The first task is we have to find out what it
10 is on that aircraft that makes that aircraft
11 vulnerable, and we call those the critical components.
12 Critical components are those components whose kill
13 either individually or jointly will lead to kill of the
14 aircraft.

15 We have tools that we use to determine the
16 critical components. They are the same ones that you
17 and I have heard mentioned at this public hearing
18 earlier, of the failure modes and effects analysis.
19 There is a failure mode; what is the effect on the
20 continued operation of the aircraft.

21 There is a fault tree analysis that is used.
22 What events must occur in order for a failure to occur.
23 We use those tools to identify these critical
24 components.

25 If we look at our F-16 cut-away here,

1 idealized aircraft, I have identified at least three
2 critical components. This is a gross simplification.
3 There are literally thousands of components on this
4 aircraft, of which perhaps many hundreds are
5 contributing to vulnerability. They are providing
6 essential functions to continue to fly.

7 The three that I have identified basically
8 represent three major systems; the crew system, the
9 fuel system and the propulsion system, the engine. Not
10 only must we identify these critical components, we
11 must identify the ways in which they are killed. That
12 may not be immediately obvious.

13 If we examine the engine, we typically think
14 of an engine as if it loses thrust the engine is
15 killed, as we would speak. It is not providing the
16 function it was designed to provide. But, that engine
17 could be hit and it could come apart, throwing blades,
18 possibly hit in the fuel tank with fuel leaking onto a
19 hot engine catching fire. We call these kill modes.

20 If we look at the fuel system which we are
21 interested in here, we have a variety of kill modes
22 that we must treat in addition to the ullage explosion
23 problem.

24 Having identified the critical components, we
25 then attempt to quantify vulnerability. We attempt to

1 put a number to it so we can compare aircraft, and the
2 number that we use is called the vulnerable area. Each
3 component has a vulnerable area. There is a vulnerable
4 area for the pilot and one for the fuel tank and one
5 for the engine.

6 But, I have a little equation at the bottom
7 of the slide on how we calculate vulnerable area
8 (indicating). The vulnerable area of a component is
9 equal to the presented area of that component times the
10 probability that component is killed given that it is
11 hit.

12 Now, a kill here could be a fuel tank
13 explosion. Keep that in mind, the probability a fuel
14 tank will explode given that that fuel tank is hit. It
15 is basically the problem that you have been dealing
16 with here.

17 We can -- for this particular aircraft in the
18 configuration shown, the aircraft has a total
19 vulnerable area for these three components made up of
20 the sum of the individual vulnerable areas.

21 Today, vulnerable area is perhaps one of the
22 requirements that is established on the design of the
23 aircraft. The aircraft shall have a vulnerable area no
24 larger than, and that is the process we go through.

25 If that fuel system is unprotected, I can

1 guaranty you that because it is the largest system on
2 the aircraft and possibly the most vulnerable system
3 that it is our major contributor, it has got to be
4 protected because we will exceed all vulnerability
5 requirements.

6 Next slide, please.

7 (Next slide shown.)

8 That brings us now to the fuel system, and
9 within the fuel tank I am showing you here -- I
10 apologize for the busy slide. I took it out of the
11 text book, and I want to attribute this slide to a
12 Lavelle Mahood (sic) who originally developed it many,
13 many years ago, and it has been used by many of us in
14 the discipline, and we are grateful for him for coming
15 up. It is a great slide.

16 You are looking at a fuel tank that is inside
17 an aircraft skin. I think you can read where the fuel
18 is. The area above the fuel, of course, we have been
19 referring to as the ullage, that vapor space.

20 What I am going to do is I am going to follow
21 the two bullets, or fragments over on the left, follow
22 them into the fuel to see what happens. Coming from
23 the left, the lower left, then, we would have an armour
24 piercing incendiary round, or a fragment penetrating
25 the outer skin of the aircraft creating friction

1 sparks. Possibly, if there is an incendiary involved,
2 the incendiary may function, and we have sparks with
3 considerable energy in them.

4 The projectile enters in through the skin
5 into the fuel tank creating the phenomena that I
6 referred to earlier, the hydrodynamic dram phenomena.
7 Intense pressure loads are put onto that tank, and it
8 can literally rip that tank apart, destroying perhaps
9 some major structure capability.

10 The fuel can come spewing out of that hole
11 down to the bottom of the aircraft and perhaps come in
12 contact with an ignition source. Perhaps a hot
13 surface, perhaps some other wires have been cut and we
14 have some arcing going. So, there is a possibility of
15 a dry bay fire in the belly of the aircraft.

16 If we move up to the upper left now
17 (indicating), we have followed that shot coming in.
18 The ullage is idealized there as being stratified into
19 three layers. Close to the fuel it is too rich, at the
20 very top it is too lean, and there in the middle we
21 have got a just right for burning. This is an
22 idealization. In reality, we don't know the conditions
23 in the ullage.

24 If you went out and measured your
25 temperature -- if that is all we had to do we would be

1 happy. Don't forget, the pilot is probably pulling
2 about five or six G-s trying to avoid this round that
3 is coming up at him. We don't know where the fuel is
4 in that tank. There is vibration, there is sloshing,
5 there is mixing. We don't know the temperature, we
6 don't know his flight profile. We don't know the
7 conditions. We deal with a large number of unknowns.
8 That is how we treat the fuel tank problem.

9 MR. ANDERSON: Dr. Ball, following on with
10 the illustration and keeping the slide on, please,
11 could you explain in a little more detail what other
12 threats to the fuel tank that might be represented by
13 the bullet, such as uncontained engine failures, which
14 would be very -- is something that is encountered in
15 the commercial aviation world, and even specifically in
16 the Boeing 747.

17 Also, the issue of -- we have called them
18 sparks here, but other sources of ignition.

19 WITNESS BALL: Yes, the -- if an engine comes
20 apart, obviously if -- it depends on where the engine
21 is. The parts that come free from the engine can pass
22 through the fuselage and into fuselage tanks, into
23 wings and into wing tanks. Possibly, a very intense
24 bird strike.

25 The tank that I have shown here is a self-

1 contained tank. Many of our tanks are what we call wet
2 wing, or integral tanks in which the tank wall is
3 basically the same as the outer skin of the aircraft,
4 and any penetration of that skin will penetrate into
5 the fuel.

6 So, any physical body, large or small, that
7 has enough energy to penetrate into the skin can either
8 create the hydraulic dram phenomena if it goes into the
9 fuel, or if it has heat energy of some form it can
10 actually create an explosion, such as a, you know, a
11 hot turbine fan blade breaking off and going through.

12 MR. ANDERSON: Just one further note of
13 clarification here. You mentioned the sparks emanating
14 from the projectiles entering the tank. Would it be
15 fair to say that that is equivalent to creating a spark
16 of, you know, electrical origin in terms of that it
17 could be quantified the same way, perhaps?

18 WITNESS BALL: I have heard of friction
19 sparks being related to the type of thing you see,
20 somebody using a grinding wheel. But, what we see are
21 friction sparks of considerably more power, more
22 energy.

23 These are sparks created by fragments, maybe
24 five hundredths of a pound, that hit the aircraft at
25 5,000 or 6,000 feet per second. This is -- there is a

1 lot of energy there.

2 If you ever see this happen, if you have ever
3 seen a warhead detonate below an aircraft, the entire
4 frame will be obscured by the light emitted by these
5 liberated fragments or friction sparks, if you will, as
6 they glow.

7 MR. ANDERSON: Thank you. Moving ahead, Dr.
8 Ball, are there any other military disciplines involved
9 in the prevention of fuel tank explosions?

10 WITNESS BALL: Yes. Yes, there is. There is
11 another one. I am getting a little out of my area now,
12 so I am going to be speaking for a discipline I am
13 really not a part of, but we share some common
14 problems. It is the systems safety discipline.

15 If I may have the next slide, please.

16 (Next slide shown.)

17 If you think about an aircraft operating in a
18 number of environments, I have identified on this slide
19 three environments and, Mr. Hall, I would like to thank
20 you for your lead-in because it was the perfect set-up
21 for what I am going to talk about.

22 If we are dealing in a man-made hostile
23 environment, there is an enemy out there who is
24 attempting to kill our aircraft, and we typically think
25 of it as an air defense, but you may think of it as a

1 terrorist. In that environment, you are dealing with
2 the combat survivability world.

3 If you look at the natural hostile
4 environment which Mr. Hall mentioned earlier where we
5 have lightning strikes, crashes, mid-air collisions,
6 severe turbulence, that kind of thing, where the
7 aircraft is stressed in many ways at much higher levels
8 than normal.

9 There we have two communities coming
10 together. We have a survivability community, which is
11 larger than the combat survivability community, and we
12 have the systems safety world.

13 If we go to the third world that we are most
14 used to, the normal operating environment, that is the
15 world of systems safety and they look at internal
16 system failures.

17 There is a spark inside the tank due to some
18 internal system failure, and they also look at things
19 like operator errors, and that is their world. We
20 overlap in this fuel explosion problem. We have many
21 other areas that we overlap.

22 Okay, next slide, please.

23 (Next slide shown.)

24 The systems safety world has different
25 terminology. You have heard me talk about

1 susceptibility and vulnerability and critical
2 components. The systems safety world deals in what
3 they call hazards and mishaps.

4 A hazard would be a fuel tank ullage with an
5 explosive vapor and an ignition source. That is a
6 hazard that leads to an explosion. That that explosion
7 causes damage to the aircraft, perhaps destroying the
8 aircraft, that is a mishap; not an accident, but a
9 mishap in the systems safety terminology. So, hazards
10 lead to explosions, and mishaps are related to the
11 damage caused by the explosion.

12 The systems safety world attempts to evaluate
13 hazards using hazard analysis. They identify hazards,
14 just like we identify critical components and how those
15 components are killed. We use the same tools, the
16 FMEA's and the fault tree analysis.

17 They rank their hazards in a different way
18 than we do. They use what is called the hazard risk
19 assessment matrix.

20 May I have the next slide, please.

21 (Next slide shown.)

22 The systems safety world has a military
23 standard, Mil 882-C, and in this mil standard they
24 describe the hazard risk assessment matrix, and it is
25 based upon two factors, if you will. What is the

1 severity of the outcome of the mishap? Is it
2 catastrophic, if the aircraft breaks apart; is it
3 critical, the aircraft is damaged; is it marginal; or,
4 is it negligible. That is one of the parameters.

5 The other factor or parameter is, how often
6 will that hazard occur? Is it frequent, probable,
7 occasional, remote, improbable, or impossible? Now,
8 these are all words in the English language, and they
9 probably mean different things to different people, and
10 I am sure the people that put this together realized
11 that, and there is some latitude as what one might mean
12 by "improbable."

13 You have to look at whether you are dealing
14 with a single aircraft in terms of improbability, or
15 whether you are dealing with a fleet of 2,000 aircraft
16 when you are talking about improbability. So, these
17 numbers have some lat -- or, these definitions have
18 some latitude, and the mil standard gives some
19 explanation of what they are thinking about for these
20 particular numbers.

21 The individual severity categories are
22 numbered one, two, three, four. The ranking given to
23 them is just the opposite; four, three, two, one. The
24 probability, A through F, is given in numerical
25 measures 6 through 1, and the hazard/risk -- or, the

1 hazard -- risk/hazard, hazard/risk index is the product
2 of the severity and the probability.

3 I have indicated there, there is basically
4 three categories. I am not sure it shows up on the
5 figure. Those that are in the dark red, if you will
6 (indicating), are numbers or products between 12 and
7 24. Those are unacceptable.

8 If a design has a hazard with an index of 15,
9 that is unacceptable and must be eliminated.
10 Controlled is the word they use, and they have various
11 ways of controlling it.

12 If it is 8 and 9 -- or, 8, 9, or 10, then it
13 is acceptable with review. In other words, the Program
14 Manager must have people look at this and decide. He
15 or she must make the decision, "yes, that is a hazard
16 and it can happen, but I am willing to accept it for my
17 aircraft."

18 The others, the A-6 through 1 is acceptable
19 without review. So, all hazards, then, are ranked
20 according to that risk -- that hazard/risk assessment
21 matrix.

22 MR. ANDERSON: Dr. Ball, the -- could we have
23 the slide back for another moment, please, slide nine?

24 (Slide shown.)

25 Could you talk a little bit about the -- you

1 talked a little bit about rating the problem as far as
2 probability of occurrence. What type of inputs would
3 typically go into establishing those categories?

4 Would it be based on testing? -- and, if so,
5 what kind of tests would be done? Would they be full
6 scale tests with a complete aircraft, or would they be
7 subsystems? Could you comment on that, please?

8 WITNESS BALL: Mr. Anderson, I beg to put
9 that question off. I don't want to say what the system
10 safety people do, because I don't know.

11 MR. ANDERSON: Okay, thank you. Now, Mr.
12 Tyson, as a tester at China Lake, would you have some
13 comments on that?

14 WITNESS TYSON: Again, I am from the aircraft
15 vulnerability community, and we do interface with the
16 Navy safety people when we are dealing with a system
17 that we have a crossover like dry bay fire
18 protection -- that is, the areas outside the fuel tank
19 that might catch on fire -- and when we have a fire
20 protection system within the tank. But, I honestly --
21 that is out of my field.

22 MR. ANDERSON: So, you know that these
23 categories exist, but we don't know where they come
24 from in terms of testing versus hazard analysis?

25 WITNESS TYSON: That is correct.

1 MR. ANDERSON: Is that a fair statement?

2 WITNESS TYSON: Yes.

3 MR. ANDERSON: Yes, okay. Dr. Ball, I think
4 we are -- we appreciate the overview very much of where
5 the military community has come and how it has got to
6 this place.

7 I think at this time I would like to ask you
8 to get into the actual concepts of preventing fuel tank
9 explosions which this discipline, of course, has
10 produced.

11 WITNESS BALL: Yes, Mr. Anderson. I hope I
12 don't inundate you with material you have seen for many
13 times throughout this public hearing, but I do need it
14 to lay some foundation, and I have discovered sometimes
15 that repetition can be helpful.

16 May I have the next slide, please?

17 (Next slide shown.)

18 There is a fuel tank. It is any one you want
19 to think of. It is in a wing, it is in a fuselage, it
20 could be carried externally. It is idealized with the
21 level of fuel.

22 In any ullage we have a mixture of air
23 containing nitrogen and oxygen, and fuel has evaporated
24 into that. It is called the ullage. There is a
25 certain amount of fuel vapor there and there is a

1 certain amount of air there.

2 Next slide.

3 (Next slide shown.)

4 We have assumed a uniform ullage. I have
5 eliminated the stratification and the non-homogeneity
6 here to make it simple. An ignition source appears.
7 In our case it could be an incendiary round, it could
8 be a hot fragment. A number of things could have
9 created it. It could be an explosive warhead. There
10 is an ignition source.

11 If the ullage surrounding -- the vapor space
12 surrounding that ignition source is combustible,
13 combustion will occur and a flame front, or combustion
14 wave will propagate roughly spherically in this
15 situation, away from that ignition source, and it will
16 move through that ullage as long as combustion can
17 continue.

18 Behind the flame front is a relatively hot,
19 relatively high pressure gas. If we look at the
20 chemical equation given at the bottom of the slide
21 (indicating) -- I apologize for that -- it is basically
22 a CN/HM, a hydrocarbon fuel, JP-4, JP-5, JP-8 Jet-A,
23 plus oxygen and nitrogen, and that is what is in the
24 ullage, three different species of gas.

25 If that energy source has sufficient energy,

1 there will be a chemical reaction and the hydrogen will
2 combine with the oxygen to give hot water vapor, the
3 carbon will combine with the oxygen to give hot CO₂,
4 the nitrogen kind of goes along for the ride. There
5 are some other products, and there is heat of
6 combustion. This is an exothermic sustained chemical
7 reaction.

8 Now, the question is, when will that occur?

9 Next slide.

10 (Next slide shown.)

11 Flammability diagram. This is a diagram in
12 which we attempt to show the region of temperature and
13 altitude for aircraft in which combustion will occur.
14 Now, it is a bit misleading to talk about temperature
15 and altitude, because we are really interested in this
16 fuel vapor and oxygen.

17 So, you will see I have on the lower axis,
18 going from left to right, temperature, but temperature
19 directly affects fuel vapor. So, as temperature goes
20 up, fuel vapor goes up. If you look at the vertical
21 axis, the altitude axis, it is a little confusing
22 because as you go up in altitude, you go down in
23 oxygen.

24 It makes it a little bit confusing, but why
25 does that happen? Well, the reason that happens is the

1 aircraft must maintain a certain differential over-
2 pressure within the ullage, and as it climbs to
3 altitude the lower pressure outside the fuel tank gets
4 smaller, and therefore the aircraft fuel ullage is
5 vented and air is released into the atmosphere and the
6 oxygen goes down.

7 Now, that gets a little bit confused by the
8 fact that there may be oxygen in the fuel, and that
9 oxygen dissolved in the fuel, and that oxygen will then
10 leave the fuel and go back up into the ullage. So,
11 instead of losing oxygen, we gain oxygen. So, it is
12 not a clear situation.

13 Now, I have indicated on this flammability
14 diagram an aircraft located at -- three aircraft
15 located at the same altitude with three different
16 temperatures, A, B and C. Okay.

17 Now let's go to the next slide.

18 (Next slide shown.)

19 We ran down to China Lake and Hardy runs some
20 tests for us and he takes the temperature and the
21 oxygen composition at altitude indicated by A, and he
22 says "I don't get combustion."

23 What he really means is that the wave front
24 doesn't go back, or if there is a little wave -- maybe
25 the over-pressure that is created by the spark is

1 really not very large.

2 Then he tests B and he says, "Yeah, real
3 nice, I have got about 100 PSI, a nice deflagration."
4 I know you have heard that word earlier. Then he goes
5 over to C and he says, "No, it didn't work, no over-
6 pressure generated by that spark."

7 So, we have a region A, too lean; a region B,
8 just right, the combustible region; and the region C,
9 too rich. We indicate the demarkation between those as
10 if it were a nice, straight line, a nice line there.
11 Well, it isn't. It is a fuzzy line. The position of
12 the line depends upon the amount of energy in the
13 spark, or, in our case, incendiary particle.

14 The more energy, the wider that region will
15 be. The location of the region along the temperature
16 axis is a function of volatility to the fuel. The
17 combustion region could be way off to the left if we
18 have a highly volatile fuel. It could be way off to
19 the right if we have a very low volatility fuel. So,
20 those are the parameters that we have to deal with when
21 we want to protect our system.

22 Now, the thing slants to the left, and you
23 kind of wonder, well, why is that? Well, that
24 complicates things because you can't just pick a
25 temperature at sea level and make it work at 30,000

1 feet. As a matter of fact, about 60,000 feet up there
2 it cuts off entirely. There is not enough oxygen out
3 there at 60,000 or above to support combustion.

4 The reason it slopes to the left is that as
5 you go up in altitude at the same temperature the fuel
6 vapor remains constant, but the oxygen level goes down
7 and, so, you go from basically being too lean -- okay,
8 you have got too much oxygen, to just the right amount
9 of oxygen, and you become combustible.

10 Now, every aircraft that flies a flight
11 profile will go through that altitude temperature
12 region, and you can draw lines and watch that thing
13 move through that region. Sometimes it will be an A,
14 sometimes it may be in B, and sometimes it will be in
15 C. Of course the question here has been, how long is
16 it in B?

17 Next slide.

18 (Next slide shown.)

19 We have some names that we give to these
20 portions of this thing. We talk about the flammability
21 limit. It is a little bit difficult when we talk about
22 flammability limits, because we use different ignition
23 sources.

24 Sometimes we use flame, sometimes we use
25 sparks. In our particular case we could use incendiary

1 rounds, or we could use high explosive warheads. So,
2 the flammability word is perhaps a bit misleading.

3 We have on the left a lower flammability
4 limit, on the right an upper flammability limit. I
5 showed arrows to indicate that those values are at sea
6 level.

7 They have values for all altitudes, but I
8 have indicated they are at sea level, and there at the
9 bottom I have taken some typical numbers out of the CRC
10 handbook, and I have given the reference there, the
11 Handbook of Aviation Fuel Properties, just to give us
12 some talking position.

13 Okay, with that as background, then, what I
14 would like to do is to take a look at that diagram and
15 figure out what we can do now to prevent combustion
16 from happening. We do that by shrinking or moving that
17 flammability region, or that combustion region.

18 Next slide, please.

19 (Next slide shown.)

20 First of all -- okay. Fuel tank explosion
21 prevention; perhaps I should say prevent/suppression
22 because prevention to me would imply that there is no
23 combustion process at all that occurs. Suppression
24 would indicate, perhaps, that there is some combustion
25 going on, but the over-pressure generated is something

1 that the fuel tank can withstand. These techniques
2 work on one or the other of those, prevention or
3 suppression.

4 First, reduction in the amount of fuel vapor;
5 basically making the ullage too lean. There are a
6 variety of ways of doing that. We can reduce the fuel
7 vapor by reducing the volatility of the fuel, by
8 cooling the fuel, by sweeping the ullage.

9 Another technique; dilution of the oxygen
10 content, which we typically refer to as inerting. Now
11 we don't have enough oxygen and we are too rich. I
12 mentioned at 60,000 feet there is not enough oxygen
13 above that to support combustion. We have inerted the
14 ullage.

15 A third technique, of course on an entirely
16 different principle, a break-down of the combustion
17 chain reaction. Combustion is a very complex process.
18 It just doesn't go from the hydrocarbon fuel and
19 oxygen, nitrogen over to hot water vapor and hot carbon
20 dioxide.

21 There are many intermediate products, and
22 there are certain chemicals that when you introduce
23 into that process will prevent it from going through
24 completion. It is called breaking down the combustion
25 chain reaction.

1 Another technique is to absorb the heat of
2 combustion. The reason the combustion wave propagates
3 through the ullage is that enough heat is liberated by
4 the process to support the combustion taking place in
5 the unburned region, and the wave moves forward. If
6 you could remove that heat, you could prevent that from
7 happening.

8 Finally, there is a physical technique;
9 interfering with the combustion mixing. Combustion
10 needs room to move. If you give it a very small space,
11 confine it, it has difficulty generating those hundred
12 PSI over-pressures. That is how we prevent combustion.

13 MR. ANDERSON: Thank you, Dr. Ball. Moving
14 from the theoretical underpinnings, if you will, of how
15 we go about designing systems, could you describe the
16 specific techniques that have been developed by the
17 Department of Defense to accomplish the goal of fuel
18 tank explosion prevention?

19 WITNESS BALL: I am just going to prevent
20 some of them. We refer to them typically as passive or
21 active. Passive means it is simply there and we don't
22 have to worry about it.

23 The first one we have on the list there is
24 foams, and a safety foam. It is an open-celled
25 reticulated polyurethane, or fibrous filler. There is

1 another one I don't have on the list called expanded
2 metal foil.

3 Nitrogen inerting is another technique. You
4 can obtain nitrogen to put into the fuel tank ullages
5 using on board liquid nitrogen, or stored in gas
6 bottles. Or, you can generate the nitrogen as the
7 aircraft flies using a system called on board inert gas
8 generating system, or OBIGS.

9 Halon 1301 is a chemical that we can -- it is
10 a gas we can put into the ullage, and it breaks down
11 the combustion chain. Unfortunately, the Halon gases
12 are no longer going to be available to us, and I think
13 Hardy and Ralph will address that issue later.

14 Ullage venting; again, reducing the fuel
15 vapor, or ullage sweeping it is sometimes called. The
16 use of additives. In other words, we can actually take
17 some additives, powder, if you will, and put it into
18 the fuel and it will reduce the volatility of the fuel.
19 It would be less likely to mist, less likely to
20 evaporate, and the use of low volatility fuel itself.

21 There is an active technique that we have
22 been investigating. Flame front detection using some
23 type of sensor, perhaps an optical sensor to detect the
24 radiation from the front, and then combustion
25 suppression by dispensing some sort of gas into the

1 ullage to suppress the development of the over-
2 pressure. Those are the techniques that have been
3 investigated, and many of them are in use today.

4 CHAIRMAN HALL: I was wondering if Dr. Ball
5 was aware of the anti-static additive they put in
6 Europe and whether that is done in the military, or
7 whether there is any anti-static additive added to
8 military fuel in this country?

9 WITNESS BALL: No, I am not. I am just not
10 aware whether there is or there isn't. It doesn't, to
11 my knowledge, have any effect on the suppression or
12 prevention of the explosion. So, I have not looked
13 into that.

14 MR. ANDERSON: Thank you, Dr. Ball. The
15 various techniques there, another term for de-
16 oxygenating the fuel I believe is scrubbing, is that
17 correct? Is that a usable term?

18 WITNESS BALL: Well, scrubbing refers to the
19 fact that fuel, as I mentioned earlier, has dissolved
20 oxygen, and if the aircraft is, we will say, sitting on
21 the ground and is re-fueled, there is a lot of oxygen
22 in that fuel.

23 As it climbs to altitude we want to get rid
24 of the oxygen. If we are going to use an inerting
25 system, we want to get the oxygen out of there, and I

1 mentioned that climbing to altitude is good because you
2 get the air out of the ullage, but you get oxygen
3 bubbling up through the fuel and into the ullage, and
4 you need to get rid of that.

5 So, what they do is they actually scrub the
6 fuel by passing, perhaps, some of this inerting gas
7 through the fuel, capturing the oxygen and dispensing
8 with it very quickly during the early times of flight.

9 MR. ANDERSON: Yes, and perhaps the reason
10 for bringing that up as a clarification is that a
11 complete nitrogen based inerting system might consist
12 of two components, and I know we will get into it
13 later, but the terminology has a tendency to get mixed
14 from here on when we are talking about different
15 systems.

16 But, the scrubbing would be the removal of
17 oxygen from the fuel by bubbling, and then the ullage,
18 which is where the oxygen ends up, is inerted with the
19 nitrogen. Is that a correct characterization of that
20 kind of system?

21 WITNESS BALL: That is my understanding.

22 MR. ANDERSON: Thank you. Can you give us
23 examples of techniques used in current U.S. military
24 aircraft, both combat aircraft, for a reference, and
25 transport aircraft that are equivalent in many ways and,

1 in fact, identical in some other ways to commercial
2 aircraft?

3 WITNESS BALL: Yes, Mr. Anderson.

4 Next slide, please.

5 (Next slide shown.)

6 Okay, I have looked around into the various
7 used military aircraft, and these are the -- these are
8 some of the aircraft of which I can speak about that I
9 have found fuel system protection. I have divided them
10 into fighters -- I should say fighter/attack and the
11 transports, the tactical and then the transport world.

12 If you will notice the -- also on there I
13 have indicted the type of system that is used and the
14 approximate year of program start. In all cases except
15 over on the right, the C-130, the fuel system
16 protection scheme that was used was original, and in
17 the original design of the aircraft.

18 Over on the C-130 which was, I believe,
19 developed -- it was started in 1950's, foam was not
20 inserted until, I believe, in Southeast Asia. But, all
21 the other aircraft actually had the foam installed at
22 the time -- or, designed to be installed at the time
23 the program started.

24 So, it gives you some idea of the fact that
25 we have been using foam since the 1960's and, Mr. Hall,

1 I believe you mentioned the foam in the Air Force
2 aircraft. The Air Force used an orange foam at that
3 time in their aircraft.

4 CHAIRMAN HALL: Senator McCain was a Naval --

5 WITNESS BALL: Yeah, I was thinking of --

6 CHAIRMAN HALL: Don't get me in trouble that
7 way.

8 WITNESS BALL: I know. I was thinking of
9 that and Marty helped me out here.

10 CHAIRMAN HALL: Did I say Air Force?

11 WITNESS BALL: I don't remember any Navy
12 aircraft that had foam in Southeast Asia, but Hardy
13 could maybe correct me here.

14 CHAIRMAN HALL: Well, that's why I wanted to
15 check.

16 WITNESS BALL: Yeah.

17 CHAIRMAN HALL: I will pull the letter up
18 here and see if that is correct, or not.

19 WITNESS BALL: The Air Force did put foam in
20 their aircraft. The Air Force was flying JP-4, the
21 Navy was flying JP-5, much less volatile, and they
22 didn't believe they had the problem the Air Force had.

23 Going back to my slide with the systems. So,
24 when you see a year on there, that is not from when the
25 aircraft started, but actually when the aircraft

1 started with that protection system.

2 So, we have the F-15 and the A-10, and for
3 the Air Force with foam. We have the Navy F-18 with
4 foam, and the current version still has foam. The EF
5 coming out has foam. The F-16 has Halon. That is
6 called part-time Halon because it is only used as the
7 aircraft flies into combat, and the F-22 is designed to
8 have OBIGS, that on board inert gas generating system.

9 Over in the transport world, the C-130 had
10 foam, the C-5 has on board liquid nitrogen, the C-17
11 has OBIGS and the V-22 is designed to have OBIGS. I
12 believe that is a representative list of military
13 aircraft that we can talk about.

14 MR. ANDERSON: Thank you, Dr. Ball. I would
15 just like to add several items. As I prepared for this
16 panel, I talked to a number of people in the civilian
17 community who were retired from the military, and I
18 wanted to find out a little more of how some of these
19 things had happened.

20 One of the areas was, as you mentioned, CO₂
21 inerting, and I would just like to mention that I was
22 told several anecdotes of testing which is, of course,
23 long buried in the official record of the B-36 in the
24 late 40's and early 50's which installed on a
25 developmental basis the CF-2 system.

1 I was also told by the same individuals that
2 the system did not prove to be successful because they
3 had difficulties with the CO₂ gas going in solution
4 with the aviation gas, which at that time was 115-145
5 grade, a very high volatility gas, and it caused
6 cavitation of the fuel pumps.

7 The other anecdotal use of flammability
8 reduction was a little interesting. During World War
9 II the Russians in their ground attack airplane, the
10 Stormovic, used anecdote exhaust gases vented through a
11 vent system into the tanks and was successful by a lot
12 of accounts in -- of suppressing fuel tank explosions,
13 or fires.

14 The last one I wanted to talk about, the C-5A
15 and C-5B aircraft, which are, of course, operating
16 today and in a very successful manner. The gentleman I
17 talked to was -- who is retired was responsible for
18 procuring that system, and I thought it was useful to
19 note that he said that the system was not delivered
20 with the airplane and not developed with the airplane,
21 but was added later.

22 The reason he told me that it was added later
23 was because three C-5's had been destroyed on the
24 ground due to fire. In one case it was a re-fueling
25 accident. In another case it was a depot entry into

1 the fuel tank where heaters or something were wrong. I
2 believe the third case was -- may have been in the air,
3 but I am not sure.

4 But, I thought it was important to mention
5 that the C-5 nitrogen system which is, I believe, a
6 liquid nitrogen system, was put on the airplane for the
7 purpose of preserving the assay.

8 I would like to move to Mr. Tyson. Good
9 afternoon, Mr. Tyson.

10 MR. TYSON: Good afternoon.

11 MR. ANDERSON: Could you share with us the
12 role that you are currently playing in reducing flight
13 hazards on U.S. Navy aircraft?

14 WITNESS TYSON: Yes. My colleagues and I at
15 China Lake test Navy and Marine Corp aircraft to
16 identify areas where we can make improvements to their
17 survivability.

18 Now, we just don't go out and shoot airplanes
19 at random. We use tools, modeling tools, as Dr. Ball
20 has illustrated in his earlier view graphs, to guide us
21 to the areas of the airplane that might need attention.

22 We also use engineering judgment. Say the
23 modelers haven't captured something that we think might
24 have a vulnerability associated with it. We will test
25 that.

1 Going back a little bit to the question you
2 referred to me earlier, we have also had the safety
3 community come to us with concerns about certain areas
4 of an airplane and say, "Could you test this, we think
5 there might be a problem." We have, and successfully
6 installed protection equipment as a result of good
7 engineering judgment by the safety people, also.

8 We also test aircraft to verify the
9 performance of installed protection systems. In
10 addition to testing aircraft, we are continually
11 involved in R&D to identify new technologies for
12 accomplishing our goals of improving survivability for
13 current and future aircraft.

14 MR. ANDERSON: The next question I would have
15 for you in that context and in that area is,
16 essentially what tests are you familiar with, or have
17 you participated in that would help us to understand
18 the methodology of testing fuel tank hazard conditions?

19 WITNESS TYSON: We have accomplished many
20 tests that specifically address fuel tank hazards. Can
21 I have my first slide, please?

22 (Slide shown.)

23 This is a series of photographs from a high
24 speed film taken by a professional photographer, Dan
25 Zern (sic), of a test I conducted collecting data to

1 support requirements for an OBIG system for a Navy
2 aircraft. As Dr. Ball mentioned, OBIG stands for on
3 board inert gas generating system.

4 As you can see from the photograph, our
5 testing in the field is very much in agreement with
6 what was presented by panel six, the Flammability panel
7 on Tuesday.

8 This particular test is a spark-ignited test.
9 The energy of this spark was nineteen jewels. What we
10 have here is a two-stage free radical branch chain
11 reaction.

12 The first stage of the reaction is visualized
13 there in the photographs by the propagation of the blue
14 flame you see extending through the volume we had
15 representing the fuel tank. That volume was thirty
16 cubic feet.

17 What is behind that blue flame is hydrocarbon
18 fragments. As Dr. Ball mentioned in his chemical
19 equation, things don't normally transition from the
20 hydrocarbon in oxygen immediately to products of
21 combustion, and that is what we are looking at there.

22 In the bottom center photograph (indicating),
23 what we have is a complete -- a very intense light
24 source derived from the triggering of those hydrocarbon
25 fragments, which are free radicals, to products of

1 combustion.

2 The pressure that is associated with the
3 first stage is on the order of one or two PSI, and the
4 pressure that is associated with that violent
5 transition to products of combustion is on the order of
6 eight times the initial pressure at ideal conditions.

7 This test was conducted at a pressure
8 altitude using standard day tables at 14,687 feet. The
9 initial temperature was ninety-five degrees and the
10 fuel was a JP-4 fuel vapor simulant.

11 The JP-4 simulant that we used consists of
12 fifteen of the highest volatile constituents of the JP-
13 4 fuel, as sampled in the stockpile across the country
14 at the time the study was done.

15 This reaction is very well described by Louis
16 and Vonelle (sic) in their classic text, "Combustion,
17 Flames and Explosions of Gases." I also want to point
18 out while we are on this slide that there is a
19 tremendous difference in a spark-ignited ullage
20 explosion and an ullage explosion initiated by the
21 threats that we are concerned with.

22 In many cases, the threats we are looking at
23 consist of thirty-five, forty, fifty grams of a high
24 explosive that detonate within the tank, and in that
25 case you don't see this nice progression of this flame

1 front that -- the fire ball is so big from the
2 detonation of the HI that you see a real rapid
3 transition to the products of combustion and a real
4 rapid rise in the pressure inside the tank.

5 Now, that is important, particularly if we
6 are trying to suppress the explosion. Dr. Ball made
7 the distinction between prevention and suppression.
8 Prevention is more like an inerting where we have a
9 fire-fighting agent existing in the ullage space before
10 we are hit.

11 If we are going to suppress an explosion, we
12 have a fire-fighting agent contained in one or many
13 containers within the ullage that then, when we detect
14 the event starting to occur, we then release our fire-
15 fighting agent and try to attack that situation before
16 it gets critical to the airplane.

17 It is a much harder problem to suppress an
18 explosion than it is to inert for an explosion, and we
19 have done both. As you might expect, since it is a
20 more difficult problem, we haven't been as successful
21 as often in suppressing explosions, but we have tested
22 some systems that show a lot of promise.

23 We have tested a system called LFE. It
24 stands for linear fire extinguisher. It is a tube that
25 contains a fire-fighting agent, and along the length of

1 the tube is a flexible linear shaped charge, and when
2 we detect an event going on, that flexible linear
3 shaped charge rips the tube open and disburses the
4 fire-fighting agent throughout the ullage.

5 As I said, in many cases we have been able to
6 affect the over-pressure significantly. There are no
7 current active explosion suppression systems installed
8 on Navy airplanes, however.

9 Let's see, can I have my next slide?

10 (Next slide shown.)

11 I am going to talk a little bit about the
12 OBIG system now. The defining word for inerting fuel
13 tank ullages was done in 1950 -- or, reported, anyway,
14 in 1955 by Stuart and Starkman who were at Wright Labs,
15 I believe, and their document is entitled "Inerting
16 Conditions for Aircraft Fuel Tanks."

17 I am sorry, could we go to the previous
18 slide, the one labelled 18.

19 (Previous slide shown.)

20 Yes. You can get a rough idea for the
21 dimensions of these membranes -- they are hairlike --
22 by the dimensions shown in the upper left. The way
23 they function is there is an air inlet. This is a high
24 pressure air that is coming from some source in the
25 airplane that I will talk about later, and the air

1 contains twenty-one percent oxygen.

2 As the air is passed through the membrane
3 module the exhaust gas, which is oxygen, CO₂ and water
4 vapor, preferentially permeates the membrane because of
5 the molecular size of those molecules is smaller than
6 the nitrogen. You can see in the output of that
7 cartoon module, the inert gas we are indicating less
8 than nine percent.

9 In that defining work by Stuart and Starkman,
10 they identified that if you inerted your ullage to less
11 than nine percent oxygen you would not get combustion
12 or an explosion event to occur in the tank, and we have
13 tested many different threats. I believe their threat
14 in their document was a spark.

15 We have tested many different threats that we
16 are concerned with, and sparks, and we have found that
17 number to be accurate. In fact, for some of the larger
18 threats that we use, we can tolerate oxygen content a
19 little higher than that and still accomplish the same
20 feat.

21 That number also changes with altitude. It
22 can -- the amount of -- the percent of oxygen you can
23 tolerate changes, goes up with altitude somewhat, and
24 as Dr. Ball indicated in the flammability curves, if
25 you get to about 60,000 feet, there is not enough

1 oxygen existing in the ambient air, anyway, to support
2 combustion.

3 Okay, can I have the next slide?

4 (Next slide shown.)

5 This is a very simplified illustration of the
6 concept of operation for an OBIG system. As indicated
7 in this slide, engine bleed air is taken and put
8 through a conditioning unit to put the air that is
9 going to be put into the air separation module within
10 the limits that the air separation module can tolerate.

11 It is also filtered, and then there is a
12 pressure regulator so you don't over-pressurize the
13 module. Then you see the module. Then there is flow
14 restrictions, and finally you see in this illustration
15 what we talked about a little bit earlier, that the gas
16 is inserted into the lower part of the tank so we can
17 take advantage of scrubbing the fuel as it makes its
18 way to the ullage, and make the ullage inert.

19 The Navy has successfully implemented OBIGS
20 on Navy and Marine Corp aircraft. When I say the Navy,
21 it is really a team of government and industry where
22 the Navy develops the requirements based on existing
23 data, or tests to define specific requirements, and
24 then the team designs and produces a system that meets
25 those requirements.

1 Can I have the next slide, please.

2 (Next slide shown.)

3 Next I would like to make a few comments
4 about foam. Foam is a mature technology that we have
5 tested many times, and it works. The mechanism by
6 which it works are listed here. It prevents passage of
7 the flame front.

8 The wetted foam -- and it is wetted with fuel
9 as a result of being within the fuel tank -- acts as a
10 heat sink, and that is a measurable part of the
11 pressure reduction that we see when we use foam as a
12 protection technique for ullage explosion.

13 The part of the fuel tank that has foam in
14 it, and they are not necessarily always 100 percent
15 patched, also provides pressure relief volume to keep
16 the pressures in the aircraft below the point at which
17 you would see structural failure.

18 I have a sample of foam here that I would
19 like to pass over to the Chairman. This is the latest
20 technology foam.

21 (Sample proffered to the Chairman.)

22 As I mentioned before, it works very
23 successfully. It does have weight and penalty volumes
24 by spec. I believe the spec requires that it weigh one
25 and a half -- no more than one and a half pounds per

1 cubic foot. The manufacturers of the foam have
2 demonstrated a lighter weight than that.

3 The spec also requires that it not retain
4 anymore than two and a half percent by volume fuel, and
5 it also -- this spec also requires that the foam not
6 displace anymore than two and a half percent by volume.

7 CHAIRMAN HALL: Mr. Tyson, I understand the
8 word foam. Reticulated, I don't. Now, what is that?

9 WITNESS TYSON: In general, I will try to
10 answer that. In general, the foam -- the material
11 called polyether is bubbled. The reticulation process
12 takes the membranes between the structure you see there
13 away so that it is an open-cell foam, and that is I
14 believe what is referred to as reticulated.

15 Do you want to help me out there, Ralph?

16 WITNESS LAUZZE: One of my favorite
17 expressions for that, sir, reticulated means the
18 interstices of foam.

19 (Laughter.)

20 It is the holes.

21 CHAIRMAN HALL: Okay, whatever. Let's pass
22 this down to the party table, would you please, Tricia,
23 so they can look at them, as well?

24 (Sample proffered to the Party Participants.)

25 MR. BIRKY: Mr. Chairman, if I might comment

1 on that, if I could, a little bit? There are generally
2 two types of foam, closed cell foams and open cell
3 foams. Closed -- you have to have open-cell in the
4 tank or you don't have any room for your fuel.

5 WITNESS TYSON: I would like to thank Jim
6 Marginette (sic) for providing that sample to us. Dr.
7 Ball also mentioned a -- an expanded aluminum foil, and
8 I have a sample of that here, too, that I would like to
9 share with you.

10 It also does a fine job of suppressing an
11 ullage explosion, and basically what it does is it
12 prevents the flame from passing, passing through the
13 ullage.

14 (Sample proffered to the Chairman and Party
15 Participants.)

16 Maybe Ralph Lauzze from the Air Force has
17 some comments he would like to add to what I have --

18 CHAIRMAN HALL: Are you familiar with a Dr.
19 S.S. Marsden? He is Emeritus at Stanford's Department
20 of Petroleum Engineering, and he sent us an article I
21 will share with you on the steaming potential and the
22 rheology of foam.

23 WITNESS TYSON: No, sir, I am not familiar
24 with him.

25 CHAIRMAN HALL: Okay, thank you. Please

1 proceed.

2 MR. ANDERSON: Thank you, Mr. Tyson. Before
3 we go over to the Air Force and Mr. Lauzze, I would
4 like to just follow up on a few items here, but the
5 last area we could follow up on first.

6 Could you -- I think we will talk a little
7 more about this, but just repeat the mechanism by which
8 the foam works.

9 WITNESS TYSON: In the testing I have done, I
10 have been able to notice a difference in the three that
11 I have listed there. It prevents passage of the flame
12 front, the wetted foam acts as a heat sink, and it
13 provides pressure relief volume.

14 In tests that I have conducted where the foam
15 was not wetted first with fuel, there is a measurable
16 difference in the over-pressure measured in the tank,
17 even though we suppressed the explosion. It is on the
18 order of a few PSI. It is not very large.

19 Then, of course, the pressure relief volume,
20 I mentioned that there are installations that work that
21 don't require 100 percent -- the volume of the tank to
22 be 100 percent packed with foam.

23 I am going to introduce a very confusing
24 term. We call that gross voiding. In other words,
25 part of the tank is voided of foam, and that minimizes

1 the weight and volume penalties associated with foam
2 being installed in a fuel tank.

3 As might be expected, if you have half of the
4 gasses in a fuel tank reacting in some way to the
5 combustion process, it will generate less pressure than
6 if all of the gasses in a fuel tank are reacting, and
7 in that manner is the last bullet where the part that
8 doesn't react adds volume for that pressure that did
9 react to expand, too.

10 MR. ANDERSON: Thank you very much. The
11 other area --

12 CHAIRMAN HALL: Well, help me. Does that
13 foam totally fill the tank, or does it lay at the
14 bottom, or is it -- what does it look like in the tank?
15 If the machinists go in, is it -- where is it?

16 WITNESS TYSON: In some installations it is
17 fully packed, yes. In -- in the F-18 aircraft the
18 wings are protected with foam and it is not fully
19 packed, and it works fine.

20 It is constructed in such a manner that the
21 foam is located on the upper portion of the fuel tank
22 and installed in between the ribs and spars, and it is
23 in the volume of the tank where the fuel is burned
24 first so that it gives protection when needed.

25 CHAIRMAN HALL: Have you ever been in a tank

1 with foam, Mr. Labelle?

2 MR. LIDDELL: Mr. Chairman, yes, and it is
3 Liddell. It is Liddell.

4 CHAIRMAN HALL: Liddell, I am sorry.

5 MR. LIDDELL: But, my experience with the
6 foam is in Air National Guard F-15's and F-4's. It
7 gave us a maintenance penalty and we wound up removing
8 it.

9 CHAIRMAN HALL: Okay, thank you. Proceed,
10 Mr. Tyson.

11 WITNESS TYSON: I am done.

12 MR. ANDERSON: Yes, I wanted to follow up on
13 your very interesting discussion of the act of
14 suppression. You mentioned the use of a shaped charge,
15 and I just -- I thought it was meaningful to have you
16 expand on that for people who are perhaps not familiar
17 with -- this is -- is it not a high explosive?

18 WITNESS TYSON: Yes, it is. That system that
19 we worked on, I did mention that there are no systems
20 currently installed on Navy aircraft that use active
21 explosion suppression.

22 That was a development test that we did, and
23 we did do testing where we had an ullage that was
24 explosive. It had a mixture of gasses in it that was
25 flammable, and we commanded the det cord to go off to

1 see if it would add to the problem, and we were not
2 able to do that. Now, of course if we were to install
3 a system like that on an airplane, I expect that it
4 would get careful scrutiny to make sure.

5 There was another issue we were also
6 concerned with when we did that investigation, and that
7 is what happens if this is under -- under -- beneath
8 the surface of the fuel and it goes off. Will that
9 then create the hydraulic dram phenomena that Dr. Ball
10 mentioned?

11 We had data -- we collected data to support
12 that, and we didn't see that as a problem, either.
13 But, those are the kinds of issues you have to deal
14 with when you go to install a system such as this for
15 protection of an aircraft.

16 MR. ANDERSON: Thank you. Could I also ask
17 you about a non-high explosive, use of perhaps gas
18 generating squibs? Has that been explored? -- a squib
19 being a small detonator device that ignites a powder
20 that burns slowly and creates a lot of gas.

21 WITNESS TYSON: Yes. As some of you might be
22 aware, that technology is being explored heavily in the
23 aircraft survivability community to partially take the
24 place of Halon, because these gas generators produce
25 copious amounts of inert gas, CO₂, nitrogen and water

1 vapor.

2 Yes, we have tested those components in the
3 application of ullage explosion suppression. It was a
4 joint effort between Northrop Grumman Corporation and
5 the Joint Technical Coordinating Group on Aircraft
6 Survivability that Dr. Ball mentioned earlier, effort
7 in testing that at China Lake.

8 It was a first look at a new technology, and
9 we hope as the technology for the application of fire
10 protection matures we can test it again. We weren't
11 all that successful the first time.

12 MR. ANDERSON: Before we leave the Navy, I
13 just want to make one more comment on the OBIGS
14 nitrogen system. It was my privilege to hear somebody
15 describe that from a chemical engineer's point of view,
16 and I believe they related the molecular sieve. Is
17 that the technology in use by the Navy on the OBIGS gas
18 converter?

19 WITNESS TYSON: The one I described was
20 permeable membrane, I believe.

21 MR. ANDERSON: Permeable membrane.

22 WITNESS TYSON: Molecular sieve is a
23 different process.

24 MR. ANDERSON: Okay.

25 WITNESS TYSON: The permeable membrane has no

1 moving parts once you get high pressure air to it. The
2 molecular sieve requires that you pressurize and
3 depressurize a bed of Z-like material so that the
4 constituents of air that you don't want can be
5 separated from the nitrogen and you can get nitrogen
6 enriched.

7 MR. ANDERSON: So, essentially where I was
8 going with that was that it was compared to a reverse
9 osmosis system, which I think people are more familiar
10 with where you desalinize sea water.

11 WITNESS TYSON: The permeable membrane is
12 very similar to that.

13 MR. ANDERSON: Yes. Okay, and one last
14 thing, Mr. Tyson. On the issue of fuels, because I
15 think that is an important issue that we will continue
16 to talk about even after we leave the military side of
17 this problem.

18 Could you talk about -- your service is
19 unique in that you have unique requirements on board
20 ship, and you are probably the prime user of JP-5 fuel
21 which has been mentioned several times here.

22 Do you have any comments on its use aboard
23 ship?

24 WITNESS TYSON: I will do my best. That is
25 not really my field. The primary reason that the Navy

1 on ship board -- and I hope I don't mis-speak -- uses
2 JP-5 is to minimize the fire hazards associated with
3 handling aircraft and refueling them on the deck.

4 JP-5 has fewer volatiles, it is a narrower
5 cut of fuel when it is distilled and therefore the
6 higher volatiles that evaporate early at lower
7 temperatures are not present, and it makes it safer to
8 handle on the deck.

9 Now, what does that do for us in the ullage
10 from an aircraft survivability point of view? It
11 simply shifts the flammability curve, the nationalized
12 flammability curve that Dr. Ball showed us, to the
13 right. It doesn't do away with it, but it puts it at a
14 different location in altitude and temperature.

15 MR. ANDERSON: Thank you very much. Mr.
16 Lauzze, could you share with us some of the development
17 concerns or considerations involved in protecting U.S.
18 Air Force aircraft?

19 MR. LAUZZE: Thank you, Mr. Anderson. Yes.
20 Like many other aircraft disciplines in aircraft
21 survivability we feel it necessary to use a systems
22 approach. We have to evaluate the whole aircraft, like
23 the engine, the flight control system and structures,
24 as well as the fuel system for vulnerabilities due to
25 enemy hits.

1 Now, we also have to balance that
2 vulnerability with the susceptibility of the system.
3 As Dr. Ball earlier stated, the probability of getting
4 hit in the first place, and obviously if you carried it
5 to an extreme we could make an airplane with such low
6 vulnerability that it couldn't perform its mission, it
7 is too heavy and would actually get hit more often.

8 So, obviously, our primary goal is to make
9 sure we approach it in a balanced way.

10 MR. ANDERSON: Following on from there, what
11 techniques does the Air Force use to suppress the fuel
12 tank explosion similar to our parallel thoughts of Mr.
13 Tyson?

14 MR. LAUZZE: The primary systems the Air
15 Force uses is -- most of them I have mentioned before.
16 The liquid nitrogen system in the C-5 I believe you
17 talked to a few minutes ago; there is an on board inert
18 gas generating system in the C-17, OBIGS; we use Halon
19 in the F-16, and I believe that is the only DOD
20 aircraft that uses Halon; and we use reticulated foam.

21 MR. ANDERSON: Could you carry on with your
22 experience in using foam both in large and small
23 aircraft?

24 MR. LAUZZE: Within the Air Force we use foam
25 in aircraft as small as the A-10 and as large as the C-

1 130. It is also used, I believe, in a similar
2 arrangement in the Navy's P-3, as similar to the C-130.

3 I did bring one slide with a little bit of a
4 success story, if you take a look at the monitor there
5 (indicating). This is a picture of an A-10 from Desert
6 Storm.

7 As you can see, the right hand wing was hit
8 by enemy fire, by what was probably a very large
9 threat. Due in a large part to the foam and just the
10 ruggedness of that airplane, we were able to bring that
11 airplane home and the pilot landed the aircraft safely.

12 The point is -- the bottom line is, foam
13 works.

14 MR. ANDERSON: Thank you. Could you talk a
15 little bit about the static interaction with the foam
16 and, you know, we talked earlier about the mechanism of
17 suppression used by the foam.

18 MR. LAUZZE: Some of the earlier foams had a
19 static problem primarily in the refueling -- in
20 refueling exercises where the foam actually -- or, the
21 fuel actually ran through the foam. A static charge
22 would build up on the foam.

23 I believe that is one reason the Air Force in
24 many cases has added an anti-static agent to our JP-8,
25 but it has also resulted in the development of the

1 newer foams, and the type that Hardy showed actually
2 has an ingredient in it that actually helps bleed off
3 the static in the fuel so we don't have the static
4 problem.

5 MR. ANDERSON: Thank you. Feel free to
6 solicit help from Mr. Tyson or Dr. Ball on this
7 question, but I think it is important to talk a little
8 bit about the future of Halon.

9 I know the Air Force is looking at
10 alternatives, and one of those alternatives I believe
11 he has all ready talked a little bit of is active
12 systems. But, could you give us anymore feel for what
13 affects that may have on your existing systems?

14 MR. LAUZZE: Well, there is two thrusts going
15 on in the Halon replacement area, basically short term.
16 We are actively -- with the Navy and the Army actively
17 looking for a chemical which we could use as a
18 replacement for the Halon chemical.

19 HFC-125 is the current chemical of choice,
20 although there are others still being looked at. There
21 are some other active type systems, as Hardy mentioned
22 earlier, and there is a long range program sponsored by
23 DOD, the Next Generation Fire Protection Program, which
24 is being highly supported by DOD.

25 So, there is both a short term fix and a long

1 term fix in the works and, Hardy, would you like to add
2 to that?

3 WITNESS TYSON: Yes, Ralph is correct. The
4 DOD is intensely interested in solving this problem for
5 our use. I would like to point out there are two
6 applications that we are looking at to replace Halon
7 for. One is fire-fighting, whether it be a system on
8 an airplane or whether it be on the ground. The other
9 is explosion protection.

10 I have tested -- we have tested at China Lake
11 the first -- some first generation chemical replacement
12 agents for Halon in the application of inerting for
13 fuel tank ullage. Then I mentioned earlier the gas
14 generator work that we did for the same application.

15 It is probably the case that we are not going
16 to find any one replacement for Halon. It will depend
17 on the application what technology we turn to.

18 MR. ANDERSON: If I understand the problem
19 correctly, the problem with replacing Halon is finding
20 something that is equally effective and is light-weight
21 and easily handled. Is that an accurate summary, or
22 have I missed something?

23 WITNESS TYSON: I am not sure I could capture
24 all of them, but that is a good summary of the most
25 important ones.

1 MR. ANDERSON: Isn't it also true that this
2 is the primary fire extinguishing agent used on
3 aircraft engines?

4 WITNESS TYSON: Yes, that is correct. It is
5 being used in aircraft engine bays or in the cells
6 since, I believe, the 70's almost exclusively, and that
7 is an issue we are working really hard.

8 MR. ANDERSON: So, that should put some
9 urgency into the search for replacement, shouldn't it?

10 WITNESS TYSON: Yes, it should.

11 MR. ANDERSON: Because without the protection
12 of engines, there is going to be a relaxation, or some
13 degradation unless an equally effective replacement is
14 found.

15 WITNESS TYSON: Yes.

16 MR. ANDERSON: Mr. Chairman, at this point I
17 would suggest that we break the panel. We are ready to
18 transition to the application of this technology in the
19 commercial aviation world.

20 CHAIRMAN HALL: Well, at this point, Mr.
21 Anderson, the Chairman is numb, so I am going to
22 suggest that we save that, because it is so important,
23 and begin at that point in the morning at nine o'clock.

24 Let me say that one item of clarification
25 here -- we discussed the Madrid 747 that was a fuel air

1 explosion because of lightning. That was line 73,
2 which I assume is the 73rd 747 off the assembly line,
3 and TWA 800 was line 153, which was the 153rd plane.

4 MR. RODRIGUES: That is correct, Mr.
5 Chairman, and line 73 was delivered in September, 1970.

6 CHAIRMAN HALL: Fine. Does anyone have
7 anything else they want to clarify before we end
8 today's session?

9 (No response.)

10 If not, I will look forward to hearing from
11 this panel again in the morning, and concluding the
12 last day of our hearing tomorrow. We will stand in
13 recess until 9:00 a.m. tomorrow morning.

14 (Whereupon, at 5:30 p.m. the hearing was
15 adjourned, to reconvene at 9:00 a.m. the following day
16 in the same location.)

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